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SHELTER FROM FALLOUT

By E. D. Callahan, L. Rosenblum, J. R. Coombe

Report No. TO-B 60-30

(Revised)

April 7, 1961

Contract No. CDM-SR-59-33

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PREPARED FOR

OFFICE OF CIVIL AND DEFENSE MOBILIZATION

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ABSTRACT

~~This report summarizes the results of~~ A survey is presented of the existing fallout shelter potential in basements and mines in the United States, and in boats on bodies of water of sufficient size and depth. Also presented is an analysis of the design, construction, and habitability of a minimum-type, improvised home basement family fallout shelter, and the shelter potential in an actual suburban community in the Northeast.

The survey shows that about 60% of the population in the U. S. would have access to basement shelter, with the figures ranging from better than 80% in OCDM Regions 1, 2, and 4 to less than 20% in Regions 3, 5, and 7. Mine shelter could be an important shelter resource for two to four million people in some 16 states, including West Virginia, Illinois, Michigan, Missouri, Kansas, Oklahoma, and New Mexico. Shelter in covered boats on lakes, rivers, and the ocean is likely to provide the best available means of protection for several million people, particularly in the states of New York, Delaware, Maryland, Virginia, Florida, Louisiana, California, Oregon, and Washington.

A family-size, sand-bag fallout shelter can be readily constructed in the basement corner by one person for a materials' cost of about $60. The shelter, which offers a protection factor of 100 against outside radiation levels, can be assembled in an hour if the materials are suitably stored along the basement walls, and realistic excursion schedules appear possible after two days even in the heaviest fallout areas. A survey of public and private buildings in a typical northeastern suburban city of 25,000 population indicated that the basements of schools, churches, and other large buildings do not offer significantly better protection than that of the average home basement (i.e., about a factor of 20).

In terms of the number of people per state who do not have even remote access to any fallout shelter (including home basements), the four most needy states are California, Texas, Florida, and Georgia.

CHAPTER 1

INTRODUCTION

1.1 SHELTER PROTECTION REQUIRED

From the fallout analysis of the combined military and industrial attack presented in Chapter 6 of Report No. TO-B 60-13 entitled "The Probable Fallout Threat Over the Continental U. S.", a number of critical areas of the country (outside the area of primary blast damage) downwind of hardened missile sites and a few of the largest industrial complexes were found to have a maximum 2-day dose of greater than 10,000 roentgens. For summer wind conditions about 5% of the area of the U. S. was covered to a 2-day dose level of 5000 r or greater.

Among the other agencies[1] that have analyzed country-wide fallout resulting from different levels of attack up to 6000 fission megatons, a 5400 fission megaton attack developed by the RAND Corp. gives the most conservative (i.e., highest) fallout estimates. It predicts that 35% of the U. S. will be covered to a level of more than 4000 r/hr at 1 hour (corresponding to a 2-day dose of about 10,000 r), and 3% will be covered to a level in excess of 8000 r/hr at 1 hour (corresponding to a 20,000 r 2-day dose). No indication is given of the per cent area in the primary blast damage rings; however, it has been estimated as follows

1) The RAND fallout model assumes a fission efficiency of 2/3, as does the Tech/Ops model; hence a 5400 fission megaton attack corresponds to a total attack of 8100 MT.

2) If all weapons were assumed to be 5 MT size, there would be 1620 of these weapons.

3) If the heavy damage area per weapon is assumed to be 150 square miles (7 mile radius), then the total heavy damage area over the country would be 244,000 square miles, or about 8% of the land area. This might be reduced by, say, 1/4 due to overlap in the heavier target concentrations, modifying the over-all damage area figure to about 6% of the U. S.

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(1) M. B. Hawkins, "Summary of Problems Relating to Local Fallout Contamination of Water Supplies" (Progress Report) Univ. of Cal., Civil Defense Research Project, Feb. 24, 1959, Figure B-1, pg. 64.

The 8000 r/hr at 1 hour area (3%) would almost certainly be included in the 6% heavy blast damage area, and can therefore be logically excluded from fallout shelter considerations. The highest levels outside the 6% blast area still approach 7000 r/hr at 1 hour, however, according to the RAND estimate, which could result in 2-day doses of 17,000 r. On the other hand, the RAND model does not take into account a ground roughness factor which has been experimentally measured (by the Chemical Corps) to be about 0.7 for the Salt Lake salt flats in Utah, and should realistically be lower for almost any other reasonably "flat" terrain. (A terrain factor of 0.55 was assumed for the fallout model described in Chapter 4 of Report No. TO-B 60-13.) Applying a terrain factor of 0.6 to the RAND model reduces the 17,000 r 2-day dose figure to 10,000 r, which is in line with the maximum levels found in the report "The Probable Fallout Threat" referred to earlier, and also agrees well with the OCDM estimate for a 6000 fission megaton attack.[1] Hence, for the purpose of establishing fallout shelter requirements, a maximum likely 2-day dose level of 10,000 r has been assumed.

In addition to <u>maximum</u> likely fallout levels, a <u>maximum</u> allowable whole body dose for the population in those very heavy fallout areas must be established before a realistic <u>minimum</u> shelter factor can be set. It is generally agreed that a dose greater than 200 r delivered over a short period of time (within a few days) will result in a significant level of radiation sickness in the population. At 100 r, however, there should be very little danger of radiation sickness. It seems reasonable, therefore, to set the maximum allowable short term (i.e., 2-day) dose at 100 r — a factor of 2 below the threshold sickness level — to make allowance for uncertainties, and to make it possible for people to start coming out of shelter at an earlier time to carry out emergency or essential activities.

This, then, sets the <u>minimum</u> shelter factor at a value of 100. A higher value would always be desirable, but is not believed to be essential insofar as averting radiation casualties is concerned. It appears that this matter is quite analogous to that of insurance — the more one leaves to his dependents, the better off they'll be, but there is a realistic minimum amount on which the survivors could be expected to get along; and since the cost of a very moderate amount is by no means negligible for the great majority of families, the minimum is as much as most of them will ever have, and many will have even less.

(1) See Reference, Page 1.

1.2 EXISTING FALLOUT SHELTER POTENTIAL AND IMPROVISED BASEMENT SHELTERS

This report presents the results of a survey of the existing fallout shelter potential in the country and an analysis of the design, construction, and habitability of a minimum-type improvised home basement family fallout shelter. Chapter 2 deals with the availability of basement shelter in the different areas of the country in terms of the number of people that can be accommodated. Chapter 3 presents a survey of the shelter potential in covered boats on lakes, rivers, and the ocean. The results of calculations to determine the distance off shore corresponding to a shelter protection factor of 100 are presented, and estimates of the number of people who might take advantage of this tactic given for the different states. Chapter 4 discusses shelter in mines, the types and location of mines considered, and a summary of the areas and populations which should consider this shelter medium.

Chapter 5 describes the design and construction of a do-it-yourself improvised home basement family fallout shelter. The shelter was designed for minimum possible cost (about $60) and minimum construction time (about 1 man hour) consistent with reasonable safety and livability. Chapter 6 presents a survey of the communal shelter potential and other essential post-attack resources in an actual suburban community of about 25,000 population. The purpose of this survey was to determine whether a communal shelter plan is feasible for the average suburban community in those areas where basements are generally available. Finally, Chapter 7 discusses the net shelter problem for the United States taking into account the potential basement, boat and mine shelter available to the population by states and OCDM regions.

In surveying the potential shelter space available in boats and mines, it was assumed that the populace would have sufficient warning time -- at least an hour, and perhaps more -- to get from their homes to the designated pre-planned shelter. This assumption appears reasonable for many areas of the country even if there is essentially no warning before the launching of a combined military and industrial attack. If, however, the enemy attacks our retaliatory forces without warning, and then, using blackmail, threatens to follow up with an industrial or population attack in the event we do not surrender, additional warning time would be available to many millions of people, thus greatly enhancing the potential value of the presently available boat and mine shelter in the country.

CHAPTER 2

AVAILABILITY OF BASEMENT SHELTER IN THE UNITED STATES

2.1 SOURCES OF INFORMATION

An investigation into the construction practices used for private homes confirmed the generally-held view that basements* are far more common in the Northeast and North Central regions of the United States than in the other regions. These areas have the lowest average winter temperatures, the greatest number of "degree-days,"** and almost universal installations of central heating. Publications of the U. S. Labor Department's Bureau of Labor Statistics on new housing provided the data for the statements below. A listing of those publications is shown in the bibliography at the end of this chapter.

Inquiries to the Federal Housing Administration (FHA), Housing and Home Finance Agency (HHFA), trade associations of home builders, banks granting mortgages and journals of the home construction industry all refer to the Bureau of Labor Statistics as the primary source of information. Data in the six publications of the Bureau of Labor Statistics were collected in the course of field surveys of new home construction during the period 1946 to 1956. Some general reference information is available on new housing built in 1940 and on wartime houses built for war workers. So far as can be determined, definitive data are not available for the total housing in any area but it is possible to estimate the number of basements in any large area from the following observations:

1) Houses built before World War II are much more likely to have basements.
2) Higher priced housing almost invariably has a higher percentage of basements.
3) Housing in large cities and in the suburbs of large cities always has a higher percentage of basements than does housing in smaller cities and rural areas in the same region.
4) Houses without central heating (in the South and Southwest) are much less likely to have basements.

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* Basements are defined as excavated and closed areas largely below grade that provide a minimum of 5 feet head room.

** Degree days is a climatological term describing quantitatively the need for supplementary heating. The number of degree days for any day is the number of degrees that the mean temperature for that day falls below 65. Average annual degree days have been tabulated for all parts of the country by the Weather Bureau.

Specific information for 15 large metropolitan areas (the 8 largest and 7 of the next 26 largest) representing almost all different densely populated parts of the country is available for the 1949 to the 1951 period. From these and from more general area data from the 1940 to the 1956 period it is possible to infer reasonably accurate figures for each state and OCDM region as noted in Sections 2.2 and 2.3.

2.2 PER CENT OF POPULATION IN EACH OCDM REGION THAT CAN BE ACCOMMODATED IN BASEMENT SHELTER

OCDM Region 1

Data for Boston, Mass. show that 90 to 95% of postwar houses have basements, while that for New York City indicate there are basements in 75 to 85% of the postwar houses. From these figures and the Northeastern* states' figure of 75 to 80%, it is estimated that in the eight states of OCDM Region 1 there is basement shelter space available for all of the 29 million residents of this region. Actually, however, there may be as many as three million people who live in homes without basements. These people reside principally in large housing developments, shore areas with high water tables and to some extent in trailer camps. The flat shore areas of Massachusetts (Cape Cod), Rhode Island, Connecticut, New York (Long Island), and New Jersey contain the overwhelming majority of the estimated three million who are several miles or more from houses with basements. These people may also be some distance from buildings which could provide equivalent shelter from radioactive fallout.

There are a great many communities in these states in which every house has a basement. In this region, long-standing custom, high priced housing suburbs and informal policies of town administrations have resisted attempts to build houses without basements. In other communities, however (even immediately neighboring ones), there may be large numbers and even a high percentage of homes without basements. More specific data could be assembled in a direct survey of the city engineers or comparable town officials in each of the large number of communities. It is not likely that state-wide data exist that are any more precise than the above estimate. It may be inferred from the high population densities of the eight states in this region that a large number of people live

* Census Bureau Northeastern States include OCDM Region 1, plus Pennsylvania.

in multiple family dwellings. Such dwellings may all have basements. The estimate of 90% for accommodation in basements of their own dwellings may therefore be low.

OCDM Region 2

Data for four of the major cities in the region are as follows:

City	Per Cent of Postwar Homes that have Basements
Philadelphia, Pa.	80 to 95
Pittsburgh, Pa.	90 to 95
Cleveland, Ohio	70 to 80
Washington, D. C.	50 to 70

From the above figures plus the figure of 75 to 80% for Northeastern states, 55 to 70% for North Central* states, and 20 to 25% for Southern** states, it is apparent that there is a significant variation among the seven states of Region 2 (including the District of Columbia). The differences are not always correlated with temperature. For example, Cleveland with 6,050 average annual degree days has 70 to 80% postwar homes with basements, while Boston with 5,940 average annual degree-days has 90 to 95% basements. An over-all figure for the region of 80% tends to obscure the very high availability (estimated at 99%) of basement shelter in Pennsylvania and the lower value of about 50% in Delaware. The estimates for Kentucky, Virginia, and West Virginia are based on indirect data. Further investigation might show that there is an even greater difference between these three states and the neighboring states of Pennsylvania and Ohio. Such a difference in the percentage of basements might be explained both by the difference in the quality of housing and the terrain rather than the difference in climate.

A preliminary study might show that large areas comprising many communities have similar building practices. Should this be so, it would be possible to assess the basement shelter availability without the need for a community by community survey as seems necessary for OCDM Region 1.

* North Central states include Ohio, OCDM Region 4, and part of Region 6.
** Southern states include Kentucky, Virginia, W. Virginia, OCDM Regions 3 and 5.

OCDM Region 3

Data for Atlanta, Ga. show that 20 to 35% of postwar homes have basements, while data for Miami, Fla. show almost no basements in the postwar homes. From these data and the figure of 20 to 25% for Southern states, it is apparent that there is significant variation among the seven states of this region. The absence of central heating and the lower cost housing add to the factors noted above for the lack of basements. The absence of basements was quite common in prewar housing so that in this region it is not likely that the percentage of basements has decreased significantly in recent years. North Carolina and Tennessee may have as many as 40% of new homes with basements. Florida has substantially none. Alabama and Mississippi are not likely to have more than 10%.

An over-all figure of 20% indicates that this region has a minimum of basement shelter. From the analysis point of view, there would be relatively little value in documenting the figures more precisely since almost no community has adequate basement shelter for its population. For planning purposes a small sample survey might be adequate for determining the amount of shelter that does exist so that plans could be made for supplementing it.

OCDM Region 4

Data for Chicago, Ill. show that 70 to 72% of postwar homes have basements, while data for Detroit, Mich. indicate that basements exist in 75 to 85% of postwar homes. From these data and the figure of 55 to 70% for the North Central states, it would seem that all five states have about the same percentage of homes with basements. An estimate for the region of 80% indicates that although the great majority of people have ready access to basement shelter, every state and probably every community has a substantial number of people who do not have access to such shelter. A survey of state officials and a sample survey of city and town engineers should indicate whether some large areas have basement shelter for the whole population, or whether providing such shelter is a problem for every community.

OCDM Region 5

Data for Dallas, Texas show that less than 1% of postwar homes have basements. From this observation and the Southern states' figure of 20 to 25%, it appears that the five states of this region may have even fewer basements than

is characteristic of OCDM Region 3. While estimates for each state have been made, they may be in substantial error. The region estimate is set at 10%. Here, as in Region 3, every community has a major problem if it is to provide shelter at least as good as the basement shelter available in the Northeastern states.

OCDM Region 6

Data for Denver, Colo. show 35 to 45% of postwar homes have basements. This fact plus the figure of 55 to 70% for the North Central states and the figure of 20 to 30% for the Western* states combine to indicate that the basement shelters in these eight states vary from 30 to 80%. It is possible that some communities and even some large areas have basement shelter for all of their residents. A sampling survey could be used to delineate the basement situation more precisely. An estimate that 65% of the regional population has access to basement shelter indicates that the problem is more serious than for Regions 1, 2, and 4, but less serious than for the Southern states.

OCDM Region 7

Data for San Francisco, Cal. show 15 to 20% of postwar homes have basements, while data for Los Angeles, Cal. show less than 1% basements in postwar homes. Using these figures and the Western states' figure of 20 to 30%, it is estimated that basement shelter in these four states could vary from 10 to 30% with an average figure of about 15%. Basement shelter or its equivalent is likely to be a major problem in every community. Discussion with state officials and a small sample survey could confirm the accuracy of this estimate.

OCDM Region 8

Data for Seattle, Wash. show that 40 to 50% of postwar homes have basements. From this observation and the analysis of neighboring regions, basement shelter in these four states appears to vary from 40 to 60%.

An over-all estimate for the region is 50%. A sample survey in Washington could establish the existence of any sizeable number of communities that provide ready access to basements for more than 90% of the population. This one state has been suggested because it has almost half of the population of the region and, as noted in Report No. TO-B 60-13, entitled "The Probable Fallout Threat over the Continental United States", the lethal fallout would be over the most heavily-populated areas in the region.

* Census Bureau Western states include Colorado, Wyoming and OCDM Regions 7 and 8.

SUMMARY

An extension of the above data shows that approximately 60% of the population in the U. S. might have access to basement shelter. Table 2.1 shows the approximate number of people (based on the 1950 Census) for whom basement shelter is available and the approximate number for whom it is not likely to be available.

TABLE 2.1

POPULATION IN EACH OCDM REGION WITH (AND WITHOUT) READY ACCESS TO BASEMENT SHELTER

OCDM Region	Estimated % of the Population with Ready Access to Basements	Population (in millions) Total	With Access	Without Access	Location
1	90	28.9	26.2	2.7	Northeast
2	80	30.0	25.0	5.0	Mid Atlantic
4	80	26.4	21.2	5.2	Great Lakes
6	65	11.6	7.9	3.7	Northern Plains
8	50	5.1	2.7	2.4	Northwest
3	20	21.0	5.1	15.9	Southeast
7	15	12.2	1.9	10.3	Far Southwest
5	10	15.2	1.8	13.4	Central South
	TOTAL	150.4	91.8	58.6	
		100%	61%	39%	

2.3 PER CENT OF POPULATION IN EACH STATE THAT CAN BE ACCOMMODATED IN BASEMENT SHELTER

The per cent of the population in each state that can be accommodated in basement shelter is shown in Table 2.2. The values listed are first approximations based on limited data recorded in the six references.

TABLE 2.2

POSTWAR (WWII) HOUSING WITH BASEMENTS AND ESTIMATED BASEMENT SHELTER ACCOMMODATIONS

State	Per Cent Of Postwar Housing With Basements	Population* (Millions)	Per Cent Of Population With Ready Access To Basements	
OCDM Region 1 -				Housing within States not likely to have high percentage of basements.
Connecticut	85	2.0	90	Ocean shore
Maine	95	.9	99	
Massachusetts	90	4.7	95	Cape Cod
New Hampshire	90	.5	99	
New Jersey	75	4.8	85	Ocean shore
New York	85	14.8	90	Long Island
Rhode Island	80	.8	90	Ocean shore
Vermont	95	.4	99	
		28.9	>90	
OCDM Region 2 -				Housing within States not likely to have high percentage of basements.
Delaware	50	.3	60	Ocean shore
Washington, D.C.	60	.8	70	
Kentucky	60	2.9	60	Low cost housing
Maryland	60	2.3	70	Ocean shore
Ohio	75	7.9	90	
Pennsylvania	95	10.5	99	
Virginia	60	3.3	70	Low cost housing
W. Virginia	60	2.0	60	Low cost housing
		30.0	>80	

(Cont'd)

* 1950 Census

TABLE 2.2 (Cont'd)

POSTWAR (WWII) HOUSING WITH BASEMENTS AND ESTIMATED BASEMENT SHELTER ACCOMMODATIONS

State	Per Cent Of Postwar Housing With Basements	Population* (Millions)	Per Cent Of Population With Ready Access To Basements	
OCDM Region 3 -				
Alabama	10	3.1	10	All states have low cost housing and high water table areas with no basements. Basements rare except in houses selling for more than $15,000. 70% of 1956 housing sold for less than $15,000.
Florida	< 1	2.8	< 1	
Georgia	20	3.4	20	
Mississippi	10	2.2	10	
N. Carolina	40	4.1	40	
S. Carolina	30	2.1	30	
Tennessee	40	3.3	40	
		21.0	>20	
OCDM Region 4 -				
Illinois	70	8.7	80	Some prewar as well as postwar houses do not have basements.
Indiana	70	3.9	80	
Michigan	80	6.4	85	
Missouri	60	4.0	70	
Wisconsin	80	3.4	85	
		26.4	>80	
OCDM Region 5 -				
Arkansas	20	1.9	20	Basements are rare except in houses selling for more than $15,000. 70% of 1956 houses sold for less than $15,000.
Louisiana	< 1	2.7	5	
New Mexico	10	.7	10	
Oklahoma	20	2.2	20	
Texas	< 1	7.7	10	
		15.2	>10	

(Cont'd)

* 1950 Census

TABLE 2.2 (Cont'd)

POSTWAR (WWII) HOUSING WITH BASEMENTS AND ESTIMATED BASEMENT SHELTER ACCOMMODATIONS

State	Per Cent Of Postwar Housing With Basements	Population* (Millions)	Per Cent Of Population With Ready Access To Basements	
OCDM Region 6 -				
Colorado	30	1.3	40	Some prewar as well as postwar houses do not have basements.
Iowa	60	2.6	70	
Kansas	40	1.9	50	
Minnesota	80	3.0	85	
Nebraska	60	1.3	70	
N.Dakota	80	.6	85	
S.Dakota	70	.6	80	
Wyoming	60	.3	70	
		11.6	>65	
OCDM Region 7 -				
Arizona	10	.7	10	Basements uncommon in prewar as well as postwar houses.
California	10	10.6	15	
Nevada	20	.2	20	
Utah	30	.7	30	
		12.2	>15	
OCDM Region 8 -				
Idaho	50	.6	60	Many prewar as well as postwar houses do not have basements. Large numbers of houses with central heating do not have basements.
Montana	60	.6	70	
Oregon	40	1.5	50	
Washington	45	2.4	50	
		5.1	>50	

* 1950 Census

Figure 2.1 summarizes on a map of the U. S. the fraction of the population in each state estimated to have readily available basement fallout protection. It is immediately apparent that the situation gets steadily worse as one goes south and west starting from the Northeast.

2.4 TRENDS IN NEW CONSTRUCTION

With the development of smaller, quieter and cleaner furnace units, the trend of construction practice in all parts of the country is to place such equipment in first floor utility rooms rather than in basements. More reliable plumbing installations and more effective insulation of a ground slab (or raised floor) from ground effects make basements less necessary for permanent homes than heretofore.

Outside of the Northeastern states expensive homes in cold regions are now often built without basements. It is believed that tradition rather than construction needs dictates the continuing Northeastern practice of building even low cost houses in large numbers with basements. No reversal of this trend was detected as recently as 1956. It is possible, however, that the Civil Defense publicity of the past few years has made both contractors, as well as the buying public, more aware of the importance of basements for fallout shelter.

A trend was already detectable in 1956 towards larger and, therefore, relatively more expensive homes. No data was published in any of the references as to the added costs of full or partial basements, but there is no doubt that houses with basements are more expensive than ones with the equivalent amount of facilities that do not have basements. It is possible that data for the 1957 to 1959 period, when available, may show a continuing of the trend toward larger houses and perhaps a new trend towards a higher percentage of basements. The wide spread use of earth moving machinery, the advantages of basements for storage, the efficiency of now widely available dehumidifying units and in particular, the effects of Civil Defense publicity might all have combined to persuade home buyers to accept the additional cost of a basement as well worthwhile. For these reasons, it is not considered likely that new housing in the near future in any part of the country will have a smaller percentage of basements than is reported for the 1946 to the 1956 period.

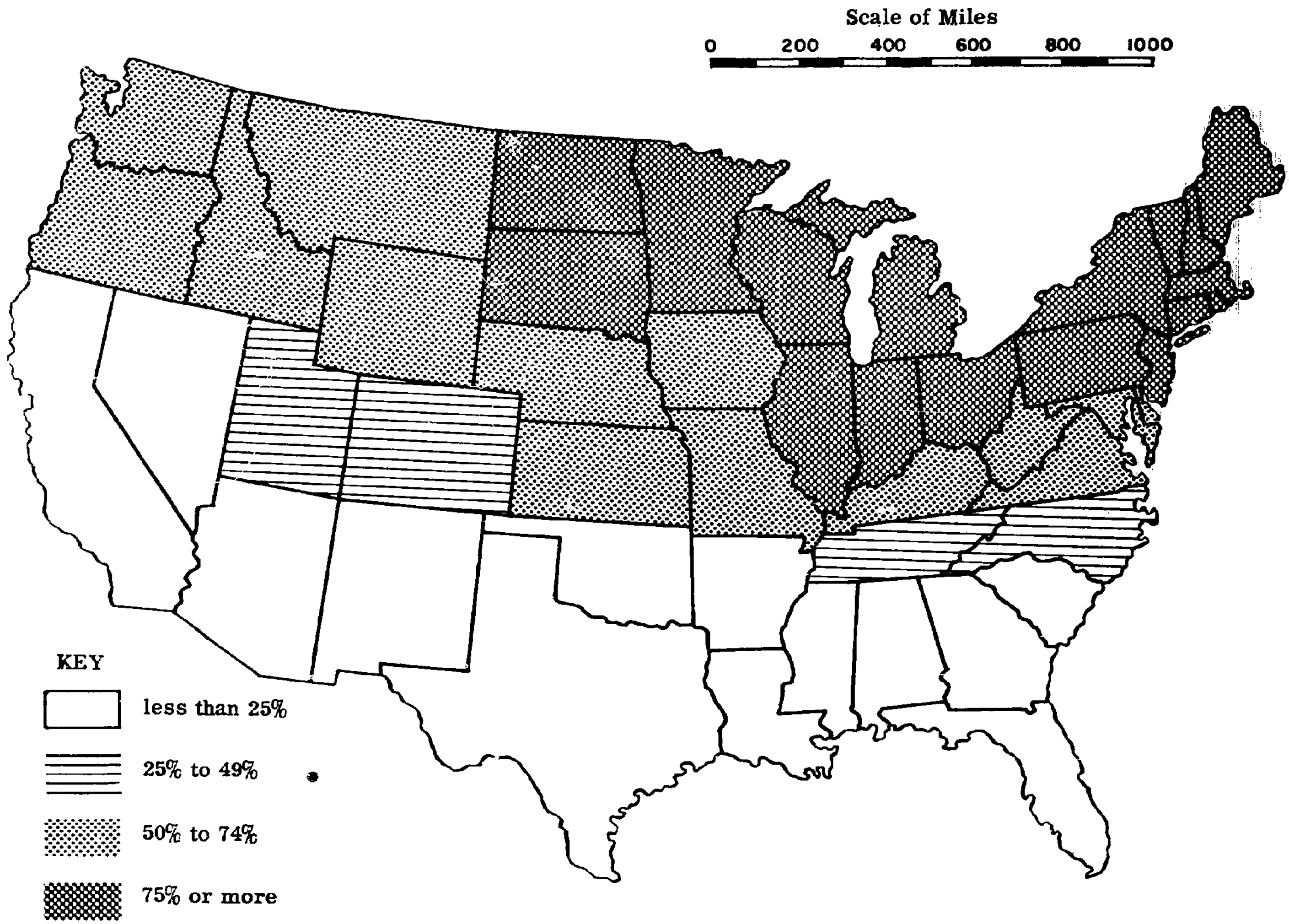

Fig. 2.1 AVAILABLE BASEMENT FALLOUT SHELTER (by states)
Approximately 60% of the Population of the Continental United States
Has Access to Basement Shelter

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CHAPTER 3

SHELTER IN COVERED BOATS ON LAKES, RIVERS AND THE OCEAN

3.1 SHELTER FACTOR VS. DISTANCE OFF SHORE

It has been suggested from time to time that covered shelter in a boat out on the water might provide a significant measure of protection from fallout. This tactic is based on the assumption that the fallout particles disperse rapidly and uniformly throughout the volume of water. Calculations of the attenuation due to the depth of water and distance from land show that depths of ten feet or more at distances of 300 or more yards off shore will provide a shelter factor of at least 100 for an observer three feet above the surface of the water.

The settling rate of particles in quiescent water (at 20°C) is given by the relation

$$T = \frac{312}{u^2} \tag{3.1}$$

where T is the time in hours for particles to fall one meter through the water and u is the particle size in microns.

From this equation we see that:

1) 10 micron particles will settle one meter in about three hours

2) 30 micron particles will settle one meter in 20 minutes

and 3) 100 micron particles will settle one meter in less than two minutes.

Since 85% of the radioactivity is believed to be associated with particle sizes greater than 30 microns, and more than 50% is associated with sizes greater than 100 microns,* one should not expect to receive a serious dose (i.e., probably not more than 25 r even in an area receiving a 2-day dose of 5,000-10,000 r) from the particles while they are settling.

* See Figure 4.1 of Report No. TO-B 60-13 entitled "The Probable Fallout Threat over the Continental U. S."

The dose received by an observer in a boat out on the water will be due to two sources: (1) the dose due to fallout on the surface of nearby land, and (2) the dose due to the fallout assumed to be uniformly distributed throughout the volume of water.

3.11 Attenuation Over a Lake Due to Ground Sources

In the case of a round lake, the attenuation at the center of the lake due to ground sources is given by the expression:

$$\alpha = \frac{R}{R_o} = \frac{E_1(u\rho) + ke^{-u\rho}}{E_1(uh) + ke^{-uh}} \qquad (3.2)$$

where R = dose rate above the center of decontaminated circle in an infinite contaminated plane

R_o = dose rate above an infinite contaminated plane

u = linear absorption coefficient of the medium (in this case, air)

k = an empirically determined constant associated with the build-up factor

h = height above the plane

$\rho = (h^2 + r^2)^{1/2}$, where "r" is the radius of the lake (i.e., the decontaminated circle)

and $E_1 = (u\rho)$ = the exponential integral

$$= \int_{u\rho}^{\infty} \frac{e^{-u\rho}}{u\rho}\, d(u\rho)$$

The dose rate at points off the center of the decontaminated circle is given by the expression:

$$R' = C' \int_0^{2\pi} \left[E_1(u\rho_o) + ke^{-u\rho_o}\right] d\phi \qquad (3.3)$$

where $\rho_o = r\left(1 - \left(\frac{x_1}{r}\right)^2 \sin^2\phi\right)^{1/2} - x_1\cos\phi$

(assuming h << r)

x_1 = lateral distance away from the center

C' = a constant

Unfortunately, this integral cannot be solved analytically, and a numerical integration would be very time-consuming without the aid of a digital computer. Hence, no attempt was made to determine the attenuation for specific values of x_1 from equation (3.3). It turns out, however, that the formula for the attenuation above the center of a decontaminated strip (in an infinite contaminated plane) — which corresponds to a river — has been tabulated, and this same formula can be used to find the attenuation at any point off the center of the decontaminated strip as shown in the next section.

3.12 Attenuation Over a River Due to Ground Sources

The attenuation above the center of a decontaminated strip is given by the expression:

$$\alpha = \frac{R}{R_o} = \frac{\displaystyle\int_{ur_o}^{\infty} \frac{(1 + kur)}{(ur)^2} e^{-ur} \left[\cos^{-1} \frac{ur_o}{ur}\right] d(ur)}{E_1(uh) + ke^{-uh}} \qquad (3.4)$$

where r_o = the half-width of the strip

and the other quantities are the same as those defined previously. For simplicity, "h" has been assumed to be much less than "r" in the numerator of equation (3.4). Although this equation is not directly integrable, numerical values for the integral have been previously tabulated. The attenuation at points off the center of the strip can be found easily by the following method:

> Let the point in question be a distance x_1 from one side of the strip and a distance x_2 from the other side. Now, find $\frac{1}{2} \frac{R}{R_o}$ for a strip of width $2x_1$ and add this value to the corresponding number for a strip of width $2x_2$. This sum is the attenuation at the point in question.

3.13 Dose Due to Particles in the Water

Due to the rapid attenuation of the activity with distance through the water, only the activity in the water within a few feet of the observer is of importance; hence we can consider the body of water to be infinite in horizontal extent without affecting the results. The attenuation above an infinite body of water due to a uniformly distributed source throughout the volume is given by the relation:

$$\alpha = \frac{R}{R_o} = \frac{1 + k}{u_1 d \left[E_1(uh) + ke^{-uh}\right]} \qquad (3.5)$$

where u_1 = linear absorption coefficient for water ($\frac{1}{u_1}$ = 0.510 feet for Cobalt 60 radiation in water)

and d = depth (in feet).

For large bodies of water, where the dose from the water is controlling, the maximum attenuation over the water turns out to be about 5.9 times the depth (in feet).

3.14 Distances Off Shore for a Shelter Factor of 100

Using the appropriate values for the constants in equations 3.4 and 3.5, Figure 3.1 was constructed showing the relation between river width and depth to obtain a shelter factor of 100, 3 feet above the center of the river. For example, for a 25-foot deep river, the minimum width required for a shelter factor of 100 is 2350 feet; for a 35-foot depth, the corresponding figure is about 1950 feet, and for 50 or more feet, it is 1800 feet. In other words, one must be at least 300 yards off the shore of a deep river to obtain a shelter factor of 100 relative to the radiation level over the nearby land. If the river is less than 17 feet deep, a shelter factor of 100 cannot be obtained regardless of width.

Figure 3.2 is a plot of the distance off shore vs. river width (and depth) for a shelter factor of 100. Here we see that the minimum "safe" distance off shore is 750 feet (250 yards) for deep, wide rivers (or for large lakes or the ocean). When the river depth is only 25 feet, however, one must be about 1000 feet off the shore of a river 2500 feet wide. In general, the corresponding distances for a shelter factor of 100 in the case of lakes will be a little greater than those for rivers, but the difference is probably negligible in all cases of practical interest.

3.15 General Requirements in Addition to Satisfactory Shelter Factor

To be habitable as a shelter, every boat should meet the following minimum requirements:

1) Provide living accommodations under shipboard cover for two weeks. The facilities should include toilets, fresh water, food storage, medical supplies, fire fighting equipment and one bunk for each person. Also, equipment to wash off any fallout that falls on the deck or other parts of the boat.

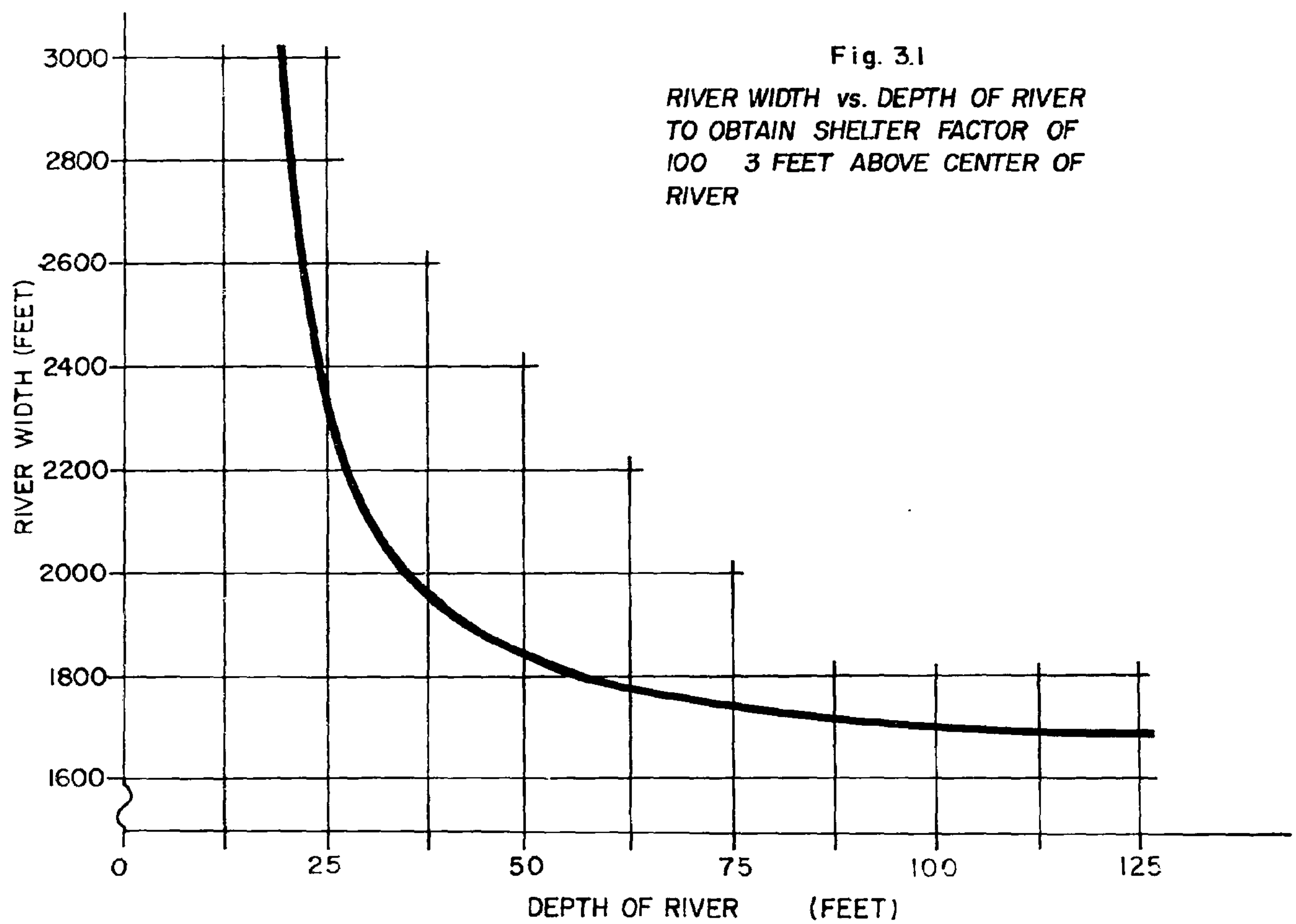


Fig. 3.1

RIVER WIDTH vs. DEPTH OF RIVER TO OBTAIN SHELTER FACTOR OF 100 3 FEET ABOVE CENTER OF RIVER

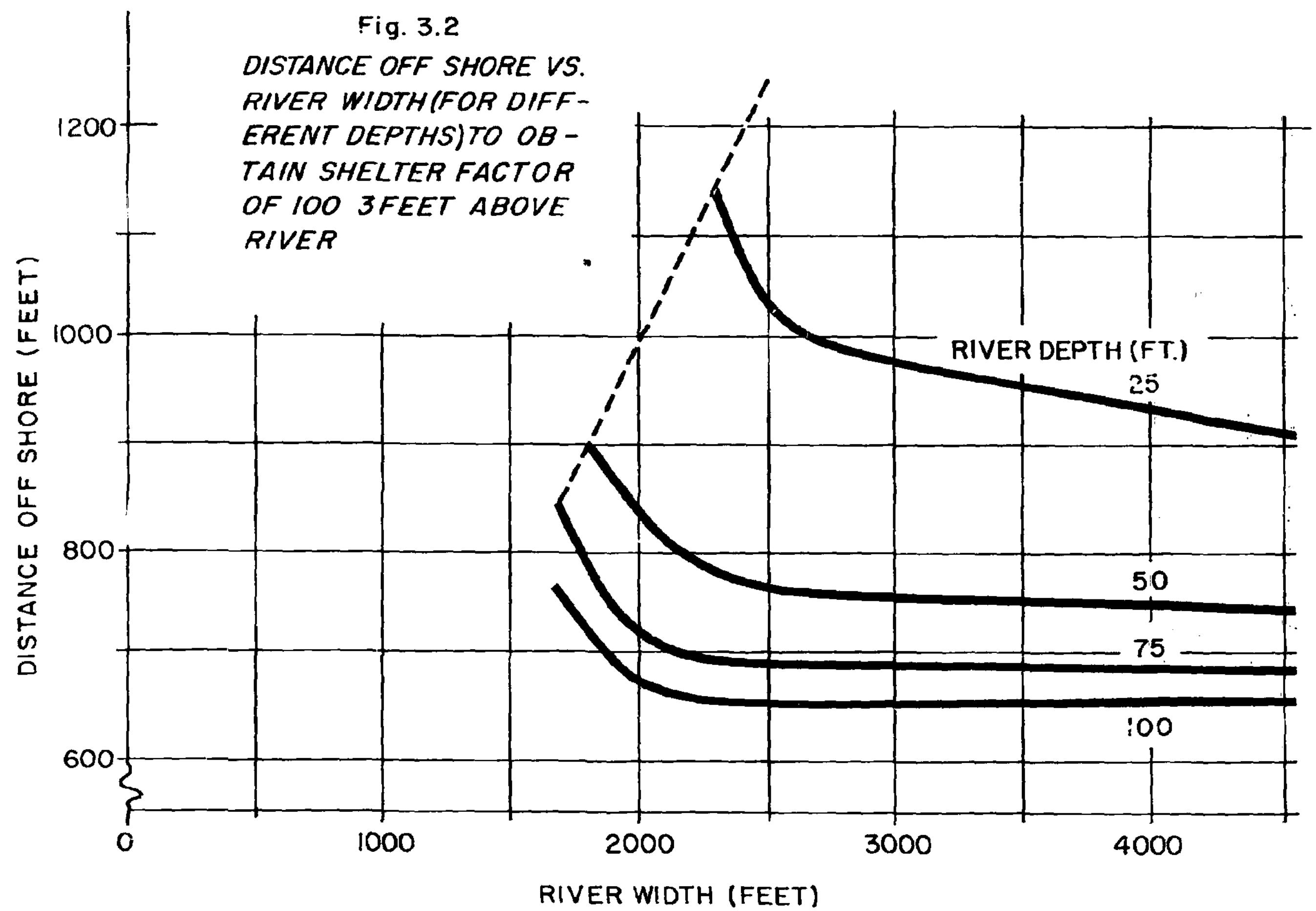


Fig. 3.2
DISTANCE OFF SHORE VS. RIVER WIDTH (FOR DIFFERENT DEPTHS) TO OBTAIN SHELTER FACTOR OF 100 3 FEET ABOVE RIVER

2) Have power or be capable of being towed by some vessel in the immediate neighborhood.

3) Have facilities for mooring in the appropriate location and plan to be at least several boat lengths from every other boat.

4) Have pumps, either hand or power-operated (if fuel is available) to take care of leaks, rain, and water from rough seas.

In any emergency operation, boats used for shelter from fallout will undoubtedly be housing more people than were ever before aboard for more than a few hours in good weather. Special care would have to be taken to be sure that the extra loading is not such as to make a hazard or a trap out of a vessel that might have provided adequate shelter for a smaller number of people.

3.2 CLASSES OF VESSELS AVAILABLE FOR SHELTER

All boats and ships of American Registry other than vessels belonging to military organizations were considered in this survey. The 4000 ships of 1000 gross tons and over account for more than 3/4 of the tonnage and shelter capability of the U. S. At any given time many of these will be on the high seas or in foreign ports and, therefore, not accessible. Our merchant fleet accounts for almost 25% of the world's shipping and a large part of it is in coastwide trade. An assumption has therefore been made that foreign shipping in our ports is usually equal in tonnage to American shipping away from our ports. These 4000 ships have a net capacity of approximately 16,000,000 tons. Most of them are in the 5,000 to 10,000 ton category.

Vessels of 5 net tons* or more are "documented" by the Bureau of Customs, are capable of providing fallout shelter and, therefore, are included in the analysis below: There are 38,000 such vessels with a net capacity of 3,000,000 tons. Most vessels are smaller than 500 tons each.

Vessels "numbered but undocumented" by the Bureau of Customs (Coast Guard) include all those longer than 16 feet if powered with permanent or detachable motors. Many of these are open runabouts, fishing boats and day sailors which would not be considered suitable for two-weeks shelter from fallout. In all there are approximately 470,000 boats in the continental United States in this category. Statistics are not readily available on their capacity. A conservative assumption is that they have 470,000 net tons capacity usable for fallout shelter.

* A cruising sailboat of 5 net tons is generally about 28 feet in over-all length. A "power boat" or fishing boat of 5 net tons is usually longer.

A summary of the above vessels and assumptions is as follows:

Category	Number	Total Capacity	Average Net Tonnage
greater than 1000 tons	4,000	16,000,000 tons	4000
5 to 1000 tons	38,000	3,000,000 tons	80
16 to 28 ft.	470,000	470,000 tons	1
TOTAL	512,000	19,000,000 tons	

3.3 SOURCES OF INFORMATION

Comprehensive records are maintained by the Bureau of Customs of the U. S. Treasury Department on merchant marine vessels. The summary document issued annually tabulates vessels by port of registry, size, kind of power, age, etc. It is known as "Merchant Marine Statistics", is published by the Bureau of Customs and is available from the U. S. Government Printing Office for 40 cents. The data shown below are from the 1958 edition. The 1959 edition, recently received, shows a 3% increase in over-all values. This change is not significantly different for any portion of the record and is almost trivial in comparison with the gross allowances noted in Section 3.6.

The vessels listed include almost all those over 5 net tons capacity. The various forms of documentation are as follows:

1) Registered - 4700 vessels engaged in foreign trade or whaling.

2) Enrolled and Licensed - 16,900 vessels of 20 net tons or more engaged in coasting trade or fishing. Also included in this category are vessels of 5 net tons or more located along the Canadian border.

3) Licensed - 16,900 vessels of 5 net tons or more including barges, scows, lighters and canal boats.

Specific details of size, rig, power, name, home port, owner, etc. are recorded in the book "Merchant Vessels of the United States 1959 (including yachts)." It is published annually by the Bureau of Customs and is available from the U. S. Government Printing Office for $6.25. Civil Defense authorities in each area planning to use covered boats for shelter for fallout may obtain all pertinent information on each boat in their area from this latter document.

Records on small boats useful for shelter are not nearly so complete. Their numbers are tabulated in the "Proceedings of the Merchant Marine Council", Vol. 16, No. 3 of March 1959 published by the U. S. Coast Guard. Page 65 of that bulletin lists the totals of "numbered and undocumented" vessels recorded in each Customs Port. Vessels in this category are machinery-propelled with capacities of less than 5 net tons. Boats of 16 feet and under with detachable motors are specifically excluded.

The grand total shown of 482,000 includes 12,000 recorded in Alaska, Hawaii and Puerto Rico. Of the 470,000 recorded in continental United States, less than half are small fishing vessels and others used in trade. A certain percentage of these and a somewhat larger percentage of the pleasure boats in this category do not have the living accommodations necessary for two-week shelter occupancy noted above. Nationwide statistics do not seem to be available on those boats in this category that are suitable, nor are the ten Coast Guard District Offices likely to have them. The 44 individual Customs Ports may have suitable detailed data but the local chapters of the Coast Guard Auxiliary and the U. S. Power Squadron will quite likely have or have access to the necessary data. Many state governments are taking over the licensing of small boats. By the end of 1961 it is likely that more complete data will be available in those states having large numbers of boats.

Information relating net ton capacity to shelter capacity is much less precise. A preliminary figure of one person per one net ton of capacity was suggested by a variety of people with Navy, Merchant Marine or pleasure boating experience. It does not seem unreasonable for any vessel provided proper preliminary arrangements are made. The only documentation available for this figure or for any vessels loaded to near maximum human capacity appears in "The Secret Roads" by Jon and David Kimche, published by Farrar, Straus and Cudahy of New York in 1955. This book records in popular fashion the "illegal" ship migration to Palestine in the 1938-1948 period. Further details of the capacity relationships are given in Section 3.5 below.

3.4 NUMBERS OF BOATS AND THEIR NET TONNAGE CAPACITY RECORDED IN EACH STATE AND OCDM REGION

The figures below are a compilation from the Bureau of Customs and Coast Guard data adjusted where necessary to give state totals. There are Customs District Offices in all but 12 states (Arkansas, Colorado, Idaho, Iowa, Kansas, Nevada, New Mexico, Oklahoma, So. Dakota, Utah, W. Virginia, Wyoming). The boats moored in these states but registered in the nearest office in an adjacent state are few and are of little consequence in this program. The small boat figures are recorded for a more limited number of Customs Port Offices and do combine large numbers of boats for adjacent states. Adjustments have been made to the available figures to arrive at reasonable estimates of the small boats in Delaware, Washington, D. C., Mississippi, and New Jersey.

Table 3.1 lists the numbers of vessels in the three major categories along with their combined tonnage. The figures are by OCDM regions and then by states. Twelve states (in six of eight regions) have more than 500,000 net tons shipping capacity and might, therefore, consider shipping an important resource not only for shelter from radioactive fallout, but also for emergency transport. These states in order of decreasing vessel tonnage registered are New York, California, Delaware, Texas, Louisiana, Maryland, Pennsylvania, Oregon, Ohio, Florida, Virginia and Washington.

Within these twelve states the most important ports (those which have greater than 50,000 net tons of shipping each) of registry are:

New York:	New York, Buffalo
California:	Los Angeles, San Francisco
Delaware:	Wilmington
Texas:	Galveston, Corpus Christi, Houston, Port Arthur
Louisiana:	New Orleans, Morgan City, Lake Charles
Maryland:	Baltimore
Pennsylvania:	Philadelphia, Pittsburgh
Oregon:	Portland
Ohio:	Cleveland, Cincinnati
Florida:	Tampa, Jacksonville, Pensacola
Virginia:	Norfolk, Newport News
Washington:	Seattle, Tacoma

Of the total 19,685,000 net tons capacity in 511,000 vessels, more than 80% are registered in the above 12 states. A sizeable percentage of the tonnage is in tankers — vessels that might be somewhat difficult to convert in a short time for use as habitable fallout shelters. Large scale use of boats and ships for shelter could best be examined by a detailed study of the facilities of the vessels registered in the 25 major ports of the 12 states listed above.

TABLE 3.1

NUMBERS, CAPACITIES, AND REGISTRY PORTS OF VESSELS LIKELY TO BE SUITABLE FOR SHELTER FROM RADIOACTIVE FALLOUT

Region	State	Number of Vessels: Commercial > 5 tons	Yachts > 5 tons	Undocumented < 5 tons	Net Tons Capacity (in 1000's)	Customs Districts
OCDM 1	Conn.	353	116	12,000	48	Bridgeport,* Hartford, New Haven, New London
	Maine	418	33	10,000	253	Portland,* Bangor, Bar Harbor, Bath, Belfast, Calais, Eastport, Jonesport, Rockland
	Mass.	1124	193	19,000	344	Boston,* Fall River, Gloucester, New Bedford, Plymouth, Salem
	N. H.	17	6	———	7	Portsmouth
	N. J.	290	33	3,000	65	Newark, Perth Amboy
	N. Y.	4836	608	71,000	4399	New York,* Albany, Buffalo,* Ogdensberg, Cape Vincent, Rouses Point, Rochester,* Oswego
	R. I.	227	65	6,000	56	Providence,* Newport
	Vt.	9	2	1,000	2	St. Albans,* Burlington
	Totals	7274	1056	122,000	5174	
OCDM 2	Del.	1448	31	5,000	1404	Wilmington
	D. C.	60	118	13,000	17	Washington
	Ky.	290	8	3,000	107	Louisville*
	Md.	1657	162	13,000	1074	Baltimore,* Annapolis, Cambridge, Crisfield
	Ohio	789	53	12,000	714	Cleveland,* Sandusky, Toledo, Cincinnati
	Pa.	2132	167	24,000	1018	Philadelphia,* Erie, Pittsburgh*
	Va.	1825	97	19,000	612	Norfolk,* Alexandria, Cape Charles, Newport News, Reedville
	W. Va.	—	—	———	—	
	Totals	8201	636	89,000	4946	
OCDM 3	Ala.	495	27	5,000	449	Mobile*
	Fla.	2992	460	34,000	675	Tampa,* Apalachicola, Fernandina Beach, Jacksonville, Key West, Miami, Pensacola, St. Augustine, West Palm Beach
	Ga.	406	22	3,000	296	Savannah,* Brunswick
	Miss.	456	28	4,000	23	Biloxi, Gulfport
	N. C.	944	37	10,000	140	Wilmington,* Beaufort, Elizabeth City, Washington
	S. C.	350	15	2,000	59	Charleston,* Georgetown
	Tenn.	202	12	7,000	64	Memphis,* Chattanooga, Nashville
	Totals	5845	601	65,000	1706	
OCDM 4	Ill.	343	81	11,000	199	Chicago,* Peoria
	Ind.	36	5	8,000	12	Indianapolis,* Evansville
	Mich.	703	88	27,000	269	Detroit,* Muskegon, Port Huron, Sault Ste. Marie
	Mo.	829	21	14,000	391	St. Louis,* Kansas City
	Wisc.	312	34	5,000	116	Milwaukee*
	Totals	2223	229	65,000	987	

* Headquarters Ports

(Cont'd)

TABLE 3.1 (Cont'd)

NUMBERS, CAPACITIES, AND REGISTRY PORTS OF VESSELS LIKELY TO BE SUITABLE FOR SHELTER FROM RADIOACTIVE FALLOUT

Region	State	Number of Vessels: Commercial > 5 tons	Yachts > 5 tons	Undocumented < 5 tons	Net Tons Capacity (in 1000's)	Customs Districts
OCDM 5	Ark.	—	—	—	—	
	La.	4242	84	26,000	1152	New Orleans,* Baton Rouge, Morgan City, Lake Charles
	N. M.	—	—	—	—	
	Okla.	—	—	—	—	
	Texas	2243	87	17,000	1394	Galveston,* Corpus Christi, Houston, Laredo,* Brownsville, Port Arthur,* Beaumont
	Totals	6485	171	43,000	2546	
OCDM 6	Col.	—	—	—	—	
	Iowa	—	—	—	—	
	Kan.	—	—	—	—	
	Minn.	382	33	6,000	130	Duluth,* Minneapolis
	Neb.	20	—	1,000	2	Omaha
	N. D.	4	2	—	—	Pembina*
	S. D.	—	—	—	—	
	Wyo.	—	—	—	—	
	Totals	406	35	7,000	132	
OCDM 7	Ariz.	—	—	—	—	Nogales
	Calif.	3357	490	42,000	2705	Los Angeles,* San Diego,* San Francisco,* Eureka
	Nev.	—	—	—	—	
	Utah	—	—	—	—	
	Totals	3357	490	42,000	2705	
OCDM 8	Idaho	—	—	—	—	
	Mont.	20	—	1,000	1	Great Falls*
	Ore.	974	56	10,000	912	Portland,* Astoria, Coos Bay
	Wash.	3588	720	25,000	576	Seattle,* Aberdeen, Bellingham, Port Angeles, Port Townsend, Tacoma
	Totals	4582	776	36,000	1489	
Grand Totals:		38,373	3,994	469,000	19,686	
		Approx. 511,000				

* Headquarters Ports

3.5 CRITERIA FOR DETERMINING SHELTER CAPACITY OF BOATS AND SHIPS

The size and characteristics of water-borne vessels are so varied that any general rule for determining shelter capacity is very likely to have exceptions. Some general considerations, however, may be as follows:

1) Individual small vessels may more readily be fitted out, loaded with people and dispatched to safer waters. From a Civil Defense Management point of view, however, it would be more difficult to organize 100 vessels of 100 tons each than to organize 10 vessels of 1000 tons each.

2) Dry cargo freighters may have fewer obstructions to fitting out efficiently as maximum capacity shelters, but the construction necessary would be far more extensive than that required by passenger liners.

3) Very large passenger liners such as the S. S. United States, registered at 53,300 tons, could hold tremendous numbers of people. With adequate warning they could be held in a U. S. port and fitted out for maximum habitation. It would, however, seem more practical to concentrate planning for the smaller and far more numerous passenger vessels in the 1000 to 10,000 ton range. These latter are somewhat less likely to be destroyed in a nuclear weapon attack and may be far more accessible to those people in heavy fallout areas who do not have adequate home basement or public building shelter facilities.

4) Tankers would in general require extensive construction work to be useful as large-scale shelters. Since they would be needed even more critically as tankers after an attack, it is unlikely that shelter plans should be made for them.

5) The dimensions of ships and boats vary widely, but some physical characteristics may be inferred from the following table of generalized dimensions:

Gross Tons	Net Tons	Length in Feet	Breadth in Feet	Draft in Feet
5	4	28	8	4
100	75	80	19	8
300	230	110	34	9
1,000	750	200	45	12
3,000	2,200	320	55	20
10,000	6,000	600	70	37

In shipping activities an equivalent of 1 net ton to 100 cubic feet is used for both gross and net tonnage. Gross tonnage covers all permanently enclosed space. Net tonnage is the remainder after deducting space occupied by the crew, the navigation facilities and the propelling power. All figures in the tables in this report are for net tonnage.

An over-all relation between net tonnage and shelter capacity has been suggested at the level of one person per net ton for all sizes of vessels. In information discussion with individuals familiar with small boats, it was learned that this is a quite valid and easily achievable figure for vessels of from 3 to 100 net tons capacity.

The 1 net ton per person relationship has been proved valid for a sizeable number of refitted passenger vessels in the 500 to 5,000-ton range. The book "The Secret Roads", cited above, records the passage of large numbers of people across the Mediterranean during the 1938 to 1948 period. No complete detailed statistics are known to exist, but it appears that upwards of 100,000 people made the voyage from French, Italian, Greek, and Rumanian ports to Palestine under conditions far more crowded than is customary for immigrant travel.

In the later years of 1947 and 1948 the crowding, for voyages ranging from a few days to several weeks, was greater than one person per ton. This was achieved by small but experienced fitting out and operating crews working with very highly motivated travelers. Restrictions on remaining below decks for most of the day were far less severe than would have been necessary under conditions of intense radioactive fallout. During these trips disease was held to a very small incidence even among badly undernourished people.

Some of the statistics cited in the book were as follows:

Ship Tonnage	Passengers	Date	Country of Origin	Vessel Name
400	900	January '47	Italy	Sereni
4,000	4,500	July '47	France	Exodus
4,500	7,500	December '47	Rumania	York
4,500	7,500	December '47	Rumania	Crescent

It is significant that in the latter two voyages the embarkation took almost two days under conditions where time was quite important. In vessels of these and larger sizes embarkation time might be a more serious limiting factor than internal capacity. It is not unlikely that as many as 20 trips of more than seven days each were made with passenger lists exceeding in number the net tonnage.* The application of the one person per net ton capacity criterion to larger vessels rests on less complete information. Large luxury liners in the range of 20,000 to 80,000 tons may routinely carry as many as 2,000 to 5,000 people respectively (passengers plus service personnel) in peacetime service. During World War II as troop transports, they carried from 5,000 to 20,000 lightly equipped troops. The living conditions were far from "comfortable" but did not approach those of the immigrant ships cited above. While large vessels in this size range might well hold one person per net ton, other considerations such as damage, access, and loading time might greatly reduce the effective shelter capacity.

The figures in Table 3.2 were calculated on the assumption that space would be available and usable in the vessels registered. For comparison among the various states no reduction factor was applied. For estimating over-all effectiveness of a ship and boat program, it has been assumed that at least 10% of the spaces (2,000,000 persons) and perhaps as many as 25% of the spaces (5,000,000 persons) could actually be made available at less cost than would be necessary for building equivalent fallout shelters on land for these people.

* Attempts were made through unofficial channels in England and Israel to document more precisely the number of such voyages, the ships used, dimensions of ships, passengers per voyage, size of crews, amounts of food and medical supplies used, incidence of disease, complements of doctors and nurses, etc. These investigations were unsuccessful. It is possible, however, that such records do exist in the archives of the tate of Israel and that access could be obtained by inquiries made through official government channels. It would also be possible to secure further information should it be of interest by direct interviewing of participants in that program. Several such individuals are now in the United States.

TABLE 3.2

BOAT AND SHIP CAPACITIES, NUMBERS OF PEOPLE LIKELY TO USE SUCH SHELTER AND MAXIMUM PERCENTAGE OF EACH STATE'S POPULATION THAT COULD BE ACCOMMODATED

Region	State	Net Tons of Vessel Cap. (in 1000's)	1950 Population (in 1000's)	Population without Basement Shelter (in 1000's)	Net to be Accommodated on Vessels (in 1000's)	Per cent of Population to be Accommodated on Vessels
OCDM 1	Conn.	48	2,007	201	48	2
	Maine	253	914	9	9	1
	Mass.	344	4,691	230	230	5
	N. H.	7	533	5	5	1
	N. J.	65	4,835	726	65	1
	N. Y.	4,399	14,830	1,483	1,483	10
	R. I.	56	792	79	56	7
	Vt.	2	378	4	2	1
	Totals	5,174	28,980	2,737	1,898	
	Region 1 SUMMARY: Greater Than 90% of Population have Access to Basements. 70% of remainder have access to boats.					
OCDM 2	Del.	1,404	318 (1/3 of capacity in barges)	127	127	40
	D. C.	17	802	241	17	2
	Ky.	107	2,945	1,180	107	4
	Md.	1,074	2,343	705	705	30
	Ohio	714	7,947	795	714	9
	Pa.	1,018	10,498	105	105	1
	Va.	612	3,319	995	612	18
	W. Va.	—	—	—	—	—
	Totals	4,946	30,178	4,951	2,387	
	Region 2 SUMMARY: Greater Than 80% of Population have Access to Basements. 50% of remainder have access to boats.					
OCDM 3	Ala.	449	3,062	2,760	449	15
	Fla.	675	2,771	2,500	675	24
	Ga.	296	3,445	2,760	296	9
	Miss.	23	2,179	1,970	23	1
	N. C.	140	4,062	2,440	140	3
	S. C.	59	2,117	1,480	59	3
	Tenn.	64	3,292	1,970	64	2
	Totals	1,706	20,928	15,880	1,706	
	Region 3 SUMMARY: Greater Than 20% of Population have Access to Basements. 10% of remainder have access to boats.					
OCDM 4	Ill.	199	8,712	1,740	199	2
	Ind.	12	3,934	780	12	-
	Mich.	269	6,372	960	269	4
	Mo.	391	3,956 (>90% of capacity in barges)	1,190	391	10
	Wisc.	116	3,435	510	116	3
	Totals	987	26,408	5,180	987	
	Region 4 SUMMARY: Greater Than 80% of Population have Access to Basements. 20% of remainder have access to boats.					

(Cont'd)

TABLE 3.2 (Cont'd)

BOAT AND SHIP CAPACITIES, NUMBERS OF PEOPLE LIKELY TO USE SUCH SHELTER AND MAXIMUM PERCENTAGE OF EACH STATE'S POPULATION THAT COULD BE ACCOMMODATED

Region	State	Net Tons of Vessel Cap. (in 1000's)	1950 Population (in 1000's)	Population without Basement Shelter (in 1000's)	Net to be Accommodated on Vessels (in 1000's)	Per cent of Population to be Accommodated on Vessels
OCDM 5	Ark.	—	1,910	1,530	—	—
	La.	1,152	2,684	2,550	1,152	43
	N. M.	—	681	610	—	—
	Okla.	—	2,233	1,780	—	—
	Tex.	1,394	7,711	6,940	1,394	18
	Totals	2,546	15,219	13,410	2,546	
	Region 5 SUMMARY:	Greater Than 10% of Population have Access to Basements. 20% of remainder have access to boats.				
OCDM 6	Col.	—	1,325	800	—	—
	Iowa	—	2,621	790	—	—
	Kan.	—	1,905	950	—	—
	Minn.	130	2,982	450	130	4
	Neb.	2	1,326	400	2	—
	N. D.	—	620	90	—	—
	S. D.	—	653	130	—	—
	Wyo.	—	291	90	—	—
	Totals	132	11,723	3,700	132	
	Region 6 SUMMARY:	Greater Than 65% of Population have Access to Basements. Less than 5% of remainder have access to boats.				
OCDM 7	Ariz.	—	750	680	—	—
	Calif.	2,705	10,586	9,000	2,705	26
	Nev.	—	160	130	—	—
	Utah	—	689	480	—	—
	Totals	2,705	12,185	10,290	2,705	
	Region 7 SUMMARY:	Greater Than 15% of Population have Access to Basements. 25% of remainder have access to boats.				
OCDM 8	Idaho	—	589	240	—	—
	Mont.	1	591	180	1	—
	Ore.	912	1,521	760	760	50
	Wash.	576	2,379	1,190	576	24
	Totals	1,489	5,080	2,370	1,337	
	Region 8 SUMMARY:	Greater Than 50% of Population have Access to Basements. 60% of remainder have access to boats.				
TOTALS:		19,685	150,701	58,518	13,698	
	SUMMARY:	Greater Than 60% of Population have Access to Basements. 23% of remainder have access to boats.				

3.6 SUMMARY OF THE NUMBERS OF PEOPLE BY OCDM REGION AND STATE WHO MIGHT TAKE ADVANTAGE OF BOAT AND SHIP SHELTER

OCDM Region 1

Boat shelter is of major importance in New York State particularly for residents of Long Island and for those in Westchester County living on Long Island Sound. The maximum capacity of more than 4,000,000 places would very likely be reduced substantially by blast damage and limited access. The tactic may also be important in Massachusetts for residents of Cape Cod and for those along Massachusetts and Buzzard Bays. Similarly it may be of importance in Rhode Island for residents along Narragansett Bay. A conservative assumption for the region is that 500,000 to 1,000,000 persons might be able to take advantage of this tactic.

OCDM Region 2

Boat shelter is of major importance in Delaware and Maryland where large numbers of people do not have access to basement shelter and live near the water. In Virginia and Ohio it may be of importance if the vessels are not destroyed and the people needing shelter have access to the boats. A conservative assumption for the region is that from 500,000 to 1,000,000 might be able to take advantage of this tactic.

OCDM Region 3

Boat shelter is of major importance in Florida. It is of some importance in Alabama and Georgia if the residents of these two states can reach boats that are undamaged. A conservative assumption is that from 200,000 to 500,000 persons might be able to take advantage of this tactic.

OCDM Region 4

Boat shelter may be of some importance in Missouri. Most of the capacity is in Missouri and Mississippi river barges. If most of these are undamaged and accessible, the estimate of 100,000 to 200,000 persons might prove overly conservative.

OCDM Region 5

Boat shelter is more important in Louisiana than in almost any other state. This state has almost no basement shelter; very little public building shelter; lots of boat shelter; lots of access considering the frontage along the Gulf of Mexico, the Mississippi River and other waterways; and a high probability that a high percentage of the vessels will be undamaged. Boat shelter may also be of some importance in Texas. It is possible, however, that a sizeable percentage of the tonnage in Texas is in tankers and that access will not be practical for many of the people needing shelter. A conservative estimate for the region is that from 500,000 to 1,000,000 persons might be able to take advantage of this tactic.

OCDM Region 6

This tactic is of little importance in Region 6. Even in Minnesota it is unlikely that as many as 30,000 people could take advantage of the boat capacity.

OCDM Region 7

Boat shelter is of major importance in California. The shipping and small boats are concentrated in the few protected harbors of the San Francisco, Los Angeles and San Diego areas. Even though there is a lot of capacity it is likely that much will be damaged and that relatively few people needing shelter will have access to the boats. These unfavorable conditions are reflected in the very conservative estimate of 200,000 to 700,000 persons who might be able to take advantage of boat shelter.

OCDM Region 8

Boat shelter is of major importance in Oregon and Washington. In both of these states access may be a serious problem so that the estimate is conservatively set at from 200,000 to 500,000 people who might take advantage of it.

The above figures were derived from Table 3.2. That table listing tonnage, population and basement shelter available for each state has been derived from the shelter data of Table 2.2 and the boat data of Table 3.1. There are 16 states noted specifically above in which boat shelter is particularly significant. Their identity,

location and likely capacity is shown in Figure 3.3. It may be noted that more capacity exists under conditions of little boat damage than could be used in Maine, Massachusetts, New York, Delaware, Maryland, Pennsylvania and Oregon. It has not been considered logical to attempt to move and allocate this left over capacity.

The conservative estimate of capacity likely to be used may be summarized as follows:

OCDM Region	Number of People Likely to Use Boat Shelter
1	500,000 to 1,000,000
2	500,000 to 1,000,000
3	200,000 to 500,000
4	100,000 to 200,000
5	500,000 to 1,000,000
6	Much less than 100,000
7	200,000 to 700,000
8	200,000 to 500,000

Total for continental United States: 2,000,000 to 5,000,000.

The conditions under which 2,000,000 to 5,000,000 people of the continental United States might realistically take advantage of the theoretical 19,000,000 spaces in boat and ship shelter may be summarized as follows:

1) United States vessels (or their equivalent) are in their home ports.

2) Vessels are not seriously damaged.

3) Vessels are accessible to the population needing shelter and then accessible to mooring or control in water of prescribed minimum depth at the prescribed minimum distance from the shore and from other vessels.

4) Vessels are fitted out to bunk people for two weeks at a capacity of up to one person per net ton.

5) Vessels are fitted out with sanitary and safety devices necessary for the complement assigned.

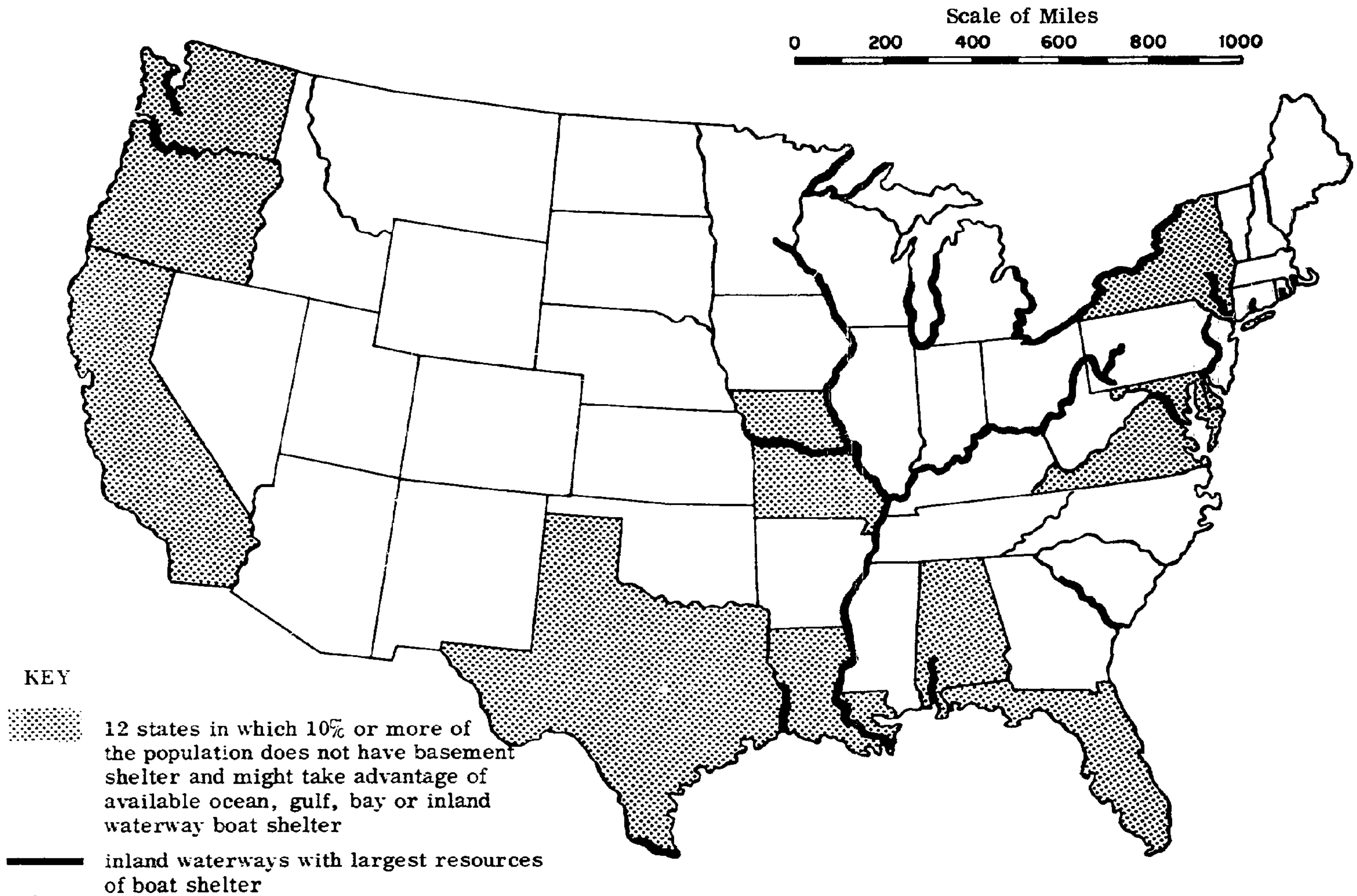


Fig. 3.3 AVAILABLE BOAT AND SHIP SHELTER (by states)

6) **Vessels are stocked with water, food, medical supplies and fuel.**

7) Vessels and population seeking shelter are organized to facilitate boarding in a time period that is safe considering the likely or actual fallout intensity.

8) Vessels are managed by suitable monitors.

9) Vessels are provided with facilities for minimizing the radioactive contamination on their exterior surfaces.

CHAPTER 4

SHELTER IN MINES

4.1 TYPES OF MINES CONSIDERED

Within the continental United States there are more than a billion square feet of underground mine space in many hundreds of mines. The most appropriate mines for use as shelter from radioactive fallout are those already identified and surveyed by the U. S. Army Corps of Engineers. In 1946, under the direction of the Munitions Board and with the cooperation of the U. S. Bureau of Mines, the Corps of Engineers selected 310 mines with an aggregate floor space of 470,820,000 square feet as most suitable for underground storage and manufacturing installations. Expert opinion available to that survey indicated that formations of granite, gypsum, limestone, sandstone, and salt have the best properties for underground use. These formations permit wide spans, high ceilings, and regular pillar arrangements. Coal mines were considered unsuitable because of low and unstable ceilings and the hazards of dust and gas explosions.

Natural caverns, such as Howe's Caverns in New York and Carlsbad Caverns in New Mexico, were considered suitable, but most other natural formations tend to have tortuous passages and very irregular interiors that would make fitting out considerably more difficult than would be the case in regularly excavated mines.

Horizontal or "drift" entries would be the most satisfactory for shelter use. Existing openings could be enlarged economically and additional entrances easily provided. "Shaft" mines, requiring elevators for entry, not only present problems in ventilation and drainage, but may present serious problems of achieving occupancy in the event of short warning time.

The 310 mines identified and located in the booklet "Underground Plants for Industry" have the following minimum characteristics:

1) Overhead and sidecover not less than 50 feet. (Such mines have a shelter factor well above 1000 so long as the entrance ways do not permit straight-line radiation paths.)
2) Floor area not less than 25,000 square feet.
3) Rooms at least 20 feet wide and 10 feet high.
4) Floor grade not greater than 3%.

A few of the sites listed have been occupied by activities concerned with shelter from nuclear attack. The first and best known of these is the Iron Mountain Atomic Storage Corp. which is located in the Burden Iron Mine at Linlithgo, New York. In the 14-year interval since the detailed survey was made, many new mines have opened up. Thus it has been assumed that such underground space, as has been occupied by facilities seeking shelter, has been more than compensated for in each area by new underground excavations.

Excavations in limestone account for approximately 65% of the mines surveyed. Salt, lead-zinc, sandstone and gypsum formations accounted for 26% of the mines. The remaining 9% included formations of borax, clay, copper, gold, iron, mica, marble, pyrite, potash, seismotite and slate.

4.2 SOURCES OF INFORMATION

The most important source of information on the location and size of underground mines suitable for shelter is the 109-page document available without charge from the Bureau of Mines entitled "Underground Plants for Industry" published January 1956 by the Dept. of Defense. This report is an unclassified summary of work carried out in 1946 under the direction of the U. S. Army Corps of Engineers. The actual survey work was done under contract W-49-129-ENG-59 by Guy B. Panero-Engineers, 420 Lexington Avenue, New York, New York. That organization prepared a series of nine reports, the most important of which for this Civil Defense study, was number six and titled "Underground Installations, Sites and Geological Formations". As is apparent from the title of the Dept. of Defense summary report, the information was assembled for use by industries essential to our military facilities.

Other sources studied included the annual "Catalog Survey and Directory Number of Mining World" and the "Keystone Coal Buyer's Manual". The former is published annually at 500 Howard Street, San Francisco 5, California. It lists only active mines (excluding coal mines) and includes a great many open pit and otherwise unsuitable sites for shelter. This directory is helpful in that it lists the exact address, the main office as well as the names of company officials for each mine. The "Keystone Coal Buyer's Manual" is published annually by McGraw-Hill Publishing Co., Inc., 330 West 42nd Street, New York, New York. As noted above, underground coal mines are far less satisfactory shelters than limestone and other formations listed. They are, however, of some importance as a last resort, particularly because there are so many of them and they exist in so many states. The 1957 edition of the Keystone Coal Buyer's Manual has a map of the United States on pages 534 and 535 showing a location of coal fields. That directory also lists the exact addresses and names of company officials for each mine.

4.3 SUITABLE MINES AND THEIR FLOOR AREA IN EACH STATE AND OCDM REGION

Table 4.2 at the end of this section lists the number and area of underground mines suitable for fallout shelter in each state. It is possible, in the event of a crisis in international affairs, that industries essential to military activities may actively seek the underground space surveyed for that purpose, and hence some of this space may not be available to Civil Defense organizations at the time it is most critically needed. It turns out, however, due to the large amounts and locations of space available, particularly in New York, Pennsylvania, Missouri, Oklahoma, New Mexico and Kansas, that both the people needing shelter and the industries desiring to relocate could likely be accommodated. The limiting factor is likely to be access time to the available entries rather than internal capacity. In each of the six states noted above, there is more than 40,000,000 square feet of space available. In each of four other states — West Virginia, Michigan, Wisconsin and Illinois — there is more than 10,000,000 square feet of space available in clean underground mines. These ten states in order of decreasing mine shelter area are shown in Table 4.1.

Of the total 470,820,000 square feet of floor space in suitable mine shelter in the United States, 94% is in states in Table 4.1. In these, as in other states, the mines are almost always in small towns and are usually more than 20 miles from a sizeable (or target) city. The only major cities listed with mines within or very close to the city limits are Detroit and Grand Rapids, Michigan; Kansas City, Missouri; St. Paul, Minnesota; and Louisville, Kentucky. It has been assumed for the purpose of this study, however, that although the enemy might well try to launch a surprise attack (i.e., only a few minutes warning at best) on our retaliatory and air defense capability, an all-out attack on industrial targets might be delayed for a period of hours while they (the enemy) assessed the effectiveness of their "first blow" and awaited our possible surrender before striking again. This period of hours would allow large numbers of people to travel 50 to 100 miles to get to suitable mine (or other) shelter.

TABLE 4.1

TEN STATES WITH LARGEST AMOUNTS OF SUITABLE MINE SHELTER SPACE

State	Suitable Mine Shelter Area (1000's sq. ft.)	Most Important Areas	Principal Adjacent City	Geological Formations
Pennsylvania	122,100	West	Around Pittsburgh	Limestone
Oklahoma	66,400	Northeast Corner	Picher	Lead and zinc
Missouri	60,900	Southwest West Central East	Joplin Kansas City Mississippi River Below St. Louis	Lead and zinc Limestone Lead and zinc
New York	50,000	West	Near Buffalo	Salt
Kansas	46,300	Center	Hutchinson	Salt
New Mexico	43,600	Southeast	Carlsbad	Potash
Michigan	13,900	Southeast West Central	Detroit Grand Rapids	Salt Gypsum
W. Virginia	13,500	Northeast Corner	Martinsburg	Limestone
Illinois	12,500	North	Ottawa	Limestone
Wisconsin	11,000	Southwest	Lancaster	Lead and zinc
Total	440,200			

TABLE 4.2

MINES IN THE U.S. SUITABLE FOR FALLOUT SHELTER AND ESTIMATES OF THE POPULATION BY STATE AND OCDM REGION THAT MIGHT BE ACCOMMODATED

State	No. Of Mines Suitable	Est. Area (sq. ft.) ($x10^{-3}$)	1950 Pop. ($x10^{-3}$)	Pop. Without Basement Shelter ($x10^{-3}$)	Net To Be Accom. In Mines ($x10^{-3}$)	% Of Pop. In Mines
			OCDM Region 1			
Conn.	—	—	2,007	201	—	—
Maine	1	30	914	10	3	0.3
Mass.	—	—	4,691	230	—	—
N. H.	—	—	533	5	—	—
N. J.	—	—	4,835	726	—	—
N. Y.	16	50,000	14,830	1,480	1,480	10
R. I.	—		792	79	—	—
Vt.	3	620	378	5	5	1.3
Totals	20	50,650	28,980	2,736	1,488	

Region 1 SUMMARY: Greater Than 90% of Population have Access to Basements.
50% of remainder could be accommodated in mines.

State	No. Of Mines Suitable	Est. Area (sq. ft.) ($x10^{-3}$)	1950 Pop. ($x10^{-3}$)	Pop. Without Basement Shelter ($x10^{-3}$)	Net To Be Accom. In Mines ($x10^{-3}$)	% Of Pop. In Mines
			OCDM Region 2			
Del.	—	—	318	127	—	—
D. C.	—	—	802	241	—	
Ky.	10	4,400	2,945	1,180	440	15
Md.	—	—	2,343	705	—	—
Ohio	11	7,800	7,947	790	780	10
Pa.	29	122,100	10,498	100	100	1
Va.	4	370	3,319	990	37	1
W. Va.	7	13,500	2,006	800	800	40
Totals	61	148,170	30,178	4,933	2,157	

Region 2 SUMMARY: Greater Than 80% of Population have Access to Basements.
40% of remainder could be accommodated in mines.

(Cont'd)

TABLE 4.2 (Cont'd)

MINES IN THE U.S. SUITABLE FOR FALLOUT SHELTER AND ESTIMATES OF THE POPULATION BY STATE AND OCDM REGION THAT MIGHT BE ACCOMMODATED

State	No. Of Mines Suitable	Est. Area (sq. ft.) ($x10^{-3}$)	1950 Pop. ($x10^{-3}$)	Pop. Without Basement Shelter ($x10^{-3}$)	Net To Be Accom. In Mines ($x10^{-3}$)	% Of Pop. In Mines
			OCDM Region 3			
Ala.	2	300	3,062	2,760	30	1
Fla.			2,771	2,500		
Ga.	5	200	3,445	2,760	20	0.6
Miss.			2,179	1,970		
N. C.	2	100	4,062	2,440	10	0.25
S. C.			2,117	1,480		
Tenn.	18	2,600	3,292	1,970	260	8
Totals	27	3,200	20,928	15,880	320	

Region 3 SUMMARY: Greater Than 20% of Population have Access to Basements.
2% of remainder could be accommodated in mines.

State	No. Of Mines Suitable	Est. Area (sq. ft.) ($x10^{-3}$)	1950 Pop. ($x10^{-3}$)	Pop. Without Basement Shelter ($x10^{-3}$)	Net To Be Accom. In Mines ($x10^{-3}$)	% Of Pop. In Mines
			OCDM Region 4			
Ill.	22	12,500	8,712	1,740	1,250	14
Ind.	5	1,800	3,934	780	180	5
Mich.	6	13,900	6,372	960	960	15
Mo.	32	60,900	3,955	1,190	1,190	30
Wisc.	18	11,000	3,435	510	510	15
Totals	83	100,100	26,408	5,180	4,090	

Region 4 SUMMARY: Greater Than 80% of Population have Access to Basements.
80% of remainder could be accommodated in mines.

(Cont'd)

TABLE 4.2 (Cont'd)

MINES IN THE U.S. SUITABLE FOR FALLOUT SHELTER AND ESTIMATES OF THE POPULATION BY STATE AND OCDM REGION THAT MIGHT BE ACCOMMODATED

State	No. Of Mines Suitable	Est. Area (sq. ft.) $(x10^{-3})$	1950 Pop. $(x10^{-3})$	Pop. Without Basement Shelter $(x10^{-3})$	Net To Be Accom. In Mines $(x10^{-3})$	% Of Pop. In Mines
			OCDM Region 5			
Ark.	1	200	1,910	1,530	20	1
La.	4	6,200	2,684	2,550	620	23
N. M.	3	43,600	681	610	610	90
Okla.	75	66,400	2,233	1,780	1,780	80
Tex.	2	700	7,711	6,940	70	1
Totals	85	117,100	15,219	13,410	3,100	

Region 5 SUMMARY: Greater Than 10% of Population have Access to Basements.
20% of remainder could be accommodated in mines.

State	No. Of Mines Suitable	Est. Area (sq. ft.) $(x10^{-3})$	1950 Pop. $(x10^{-3})$	Pop. Without Basement Shelter $(x10^{-3})$	Net To Be Accom. In Mines $(x10^{-3})$	% Of Pop. In Mines
			OCDM Region 6			
Colo.			1,325	800		
Iowa	3	1,000	2,621	790	100	4
Kan.	13	46,300	1,905	950	950	50
Minn.	3	300	2,982	450	30	1
Nebr.	2	700	1,326	400	70	5
N. D.			620	90		
S. D.			653	130		
Wyo.			291	90		
Totals	21	48,300	11,723	3,700	1,150	

Region 6 SUMMARY: Greater Than 65% of Population have Access to Basements.
30% of remainder could be accommodated in mines.

(Cont'd)

TABLE 4.2 (Cont'd)

MINES IN THE U.S. SUITABLE FOR FALLOUT SHELTER AND ESTIMATES OF THE POPULATION BY STATE AND OCDM REGION THAT MIGHT BE ACCOMMODATED

State	No. Of Mines Suitable	Est. Area (sq.ft.) ($x10^{-3}$)	1950 Pop. ($x10^{-3}$)	Pop. Without Basement Shelter ($x10^{-3}$)	Net To Be Accom. In Mines ($x10^{-3}$)	% Of Pop. In Mines
			OCDM Region 7			
Ariz.	1	100	750	680	10	2
Calif.	9	2,700	10,586	9,000	270	3
Nev.	3	500	160	130	50	31
Utah			689	480		
Totals	13	3,300	12,185	10,290	330	

Region 7 SUMMARY: Greater Than 15% of Population have Access to Basements.
3% of remainder could be accommodated in mines.

State	No. Of Mines Suitable	Est. Area (sq.ft.) ($x10^{-3}$)	1950 Pop. ($x10^{-3}$)	Pop. Without Basement Shelter ($x10^{-3}$)	Net To Be Accom. In Mines ($x10^{-3}$)	% Of Pop. In Mines
			OCDM Region 8			
Idaho			589	240		
Mont.			591	180		
Ore.			1,521	760		
Wash.			2,379	1,190		
Totals			5,080	2,370		

Region 8 SUMMARY: Greater Than 50% of Population have Access to Basements.
None of remainder could be accommodated in mines.

GRAND TOTAL:	310	470,820	150,701	58,499	12,635

SUMMARY: Greater Than 60% of Population have Access to Basements.
22% of remainder could be accommodated in mines.

4.4 CRITERIA FOR DETERMINING SHELTER CAPACITY OF MINES

Various Civil Defense reports have used a minimum space per person figure on the order of 100 cubic feet. If provision in mine shelters is made for multi-deck bunks of at least four bunks high, it seems quite reasonable to allow 10 square feet of floor space per person (40 square feet of floor space per four people). This specification provides for space below bunks, aisles, and service facilities. While bunks decked four high is a reasonable maximum for constructed shelters (as reported in conversations with the human factor engineers of Dunlap Associates of Stamford, Conn.), it is a conservative limit for underground mines with minimum ceiling heights of 10 feet and typical heights of 15 to 30 feet.

Mines with between 25,000 and 100,000 square feet of area could be equipped to house from 2,500 to 10,000 people. Access should be through more than one entry wherever possible.

Mines of 100,000 to 1,000,000 square feet floor area could be equipped to house from 10,000 to 100,000 people, but access is probably impractical unless there is at least one drift entrance per 10,000 people or one shaft elevator for perhaps each 2,000 people.

Of the 310 mines listed, 84 have areas in excess of 1,000,000 square feet. Few of these have one or more drift entrances per 100,000 square feet so that it is unlikely that they could be used to shelter people at the rate of one person per 10 square feet unless further entrances were excavated. Direct examination would be necessary at each mine site to determine the technical feasibility and cost of such additional construction. The tabulation by states of shelter spaces in Table 4.2 assumes that provision could be made where necessary for additional entrances. These figures are used for state to state comparisons and are based on the assumption that basement (but not boat) shelter will be used in preference to mine shelter wherever available.

4.5 ESTIMATES OF AREAS AND NUMBERS OF PEOPLE WHO MIGHT TAKE ADVANTAGE OF MINE SHELTER IN EACH OCDM REGION

OCDM Region 1

Mine shelter is of major importance in some parts of New York state. The mine shelter is not in the same place as the boat shelters and therefore could complement it very well. Of the 5,000,000 mine shelter spaces in 20 mines of OCDM Region 1, from 300,000 to 600,000 spaces might be readily usable.

OCDM Region 2

Mine shelter is of great importance in West Virginia and of major importance in Kentucky, Ohio and Pennsylvania. It is unlikely that more than a very small percentage of the 12,000,000 spaces in Pennsylvania would be used, since the people living greater than five miles away from these mine shelter areas all have basements and would probably prefer to stay in them. In Kentucky, the city of Louisville has 25,000 shelter spaces accessible through four drift entrances of one mine. These are a very important resource. In summary, the 15,000,000 shelter spaces in 61 mines of this region would probably not be usable by more than 300,000 to 600,000 people.

OCDM Region 3

Tennessee is the only state in this region with appreciable mine shelter capacity. Of the 300,000 shelter spaces in 27 mines, perhaps 100,000 people might actually find this to be their best shelter alternative since there is little basement or public building shelter and not enough boat shelter in this region.

OCDM Region 4

Mine shelter is of great importance in Missouri and of major importance in Michigan, Illinois and Wisconsin. In particular, there are 1,250,000 shelter spaces all with drift access (49 entrances) in Kansas City and nearby Independence, Missouri. At least 100,000 of these spaces (and maybe many more) could be used by people in and around Kansas City who either do not have basements or whose basement shelter is not adequate. The 6,000,000 shelter spaces in three major regions in Missouri are far more than enough to house the whole state's population. This state, perhaps better than any other, could investigate in detail the shelter

possibilities in its 32 mines and prepare both a short notice shelter program for perhaps 100,000 people as well as a longer notice evacuation program for many more. Missouri is one of the two states in the country with inadequate basement shelter and with a large capacity in both mines and boats. In this state a direct comparison could be made between the two alternate shelter systems.

Similarly, Detroit, Michigan has more than 800,000 mine shelter spaces and Grand Rapids has over 400,000. The mines in both of these cities, however, have shaft entrances and only four in each. The percentage of basements in Michigan is higher than in Missouri, but the net population without access to basements is about the same. As many as 100,000 people may easily be accommodated in the Detroit and Grand Rapids mines.

The large number of mine shelter spaces in Illinois and Wisconsin are somewhat remote from densely populated centers. They could, however, be used as large scale evacuation centers. Certainly 500,000 and quite possibly more than 1,500,000 people in Region 4 could be accommodated in the 10,000,000 shelter spaces available in 83 mines.

OCDM Region 5

The very large number of spaces (6,640,000) in Oklahoma are all in the one small town of Picher. The town's population is less than 5,000 while its county, Ottawa, of approximately 1,000 square miles in area, has a population of 32,000. The 75 mines in Picher have 237 shaft entries. On a several day evacuation basis, these mines could provide shelter for people from Oklahoma, Arkansas and Kansas. It is unlikely that more than 200,000 people, even with several days for evacuation, could take advantage of this capability.

Similarly, New Mexico has all of its 4,360,000 mine shelter spaces in one small town, Carlsbad, which has a small population of 18,000 in a county with a population of 41,000 and an area of approximately 3600 square miles. The three mines with six shaft entrances all together could provide excellent shelter for these near-by people and could accommodate more than 3,000,000 persons from further away in New Mexico and Texas if it were practical to provide several day evacuation.

A fair estimate for this region is that from 300,000 to 600,000 people might actually take advantage of the almost 12,000,000 shelter spaces available in 85 mines.

OCDM Region 6

Mine shelter is of major importance in Kansas. The two mines in Kansas City have 20 drift entrances and shelter space for over 200,000 people. The utilization of this space probably should be coordinated with similar large amounts of good mine shelter space, across the adjacent state border in Kansas City, Missouri. The other shelter space in Kansas is somewhat remote from densely populated centers but could be used on a several day evacuation basis. Utilization will, however, be further limited by the small number of entrances mostly of shaft type to these eleven other mines.

A small amount of mine shelter exists in St. Paul, Minnesota and somewhat larger amounts exist in less densely populated parts of Iowa and Nebraska. A conservative estimate for the region is that from 300,000 to 600,000 persons could take advantage of the almost 5,000,000 shelter space in the 21 mines.

OCDM Region 7

Mine shelter is an important resource for the relatively small population of Nevada. The mine shelter space in California is somewhat larger and is an important resource for those people living in the central part of the state. The total mine shelter space in the region is, however, small when compared with the need or with the amounts available in other regions. It is estimated that between 100,000 and 200,000 people could take advantage of the more than 300,000 mine shelter spaces in 13 mines.

OCDM Region 8

There is virtually no mine shelter space available in OCDM Region 8.

4.6 SUMMARY OF MINE SHELTER POTENTIAL IN THE UNITED STATES

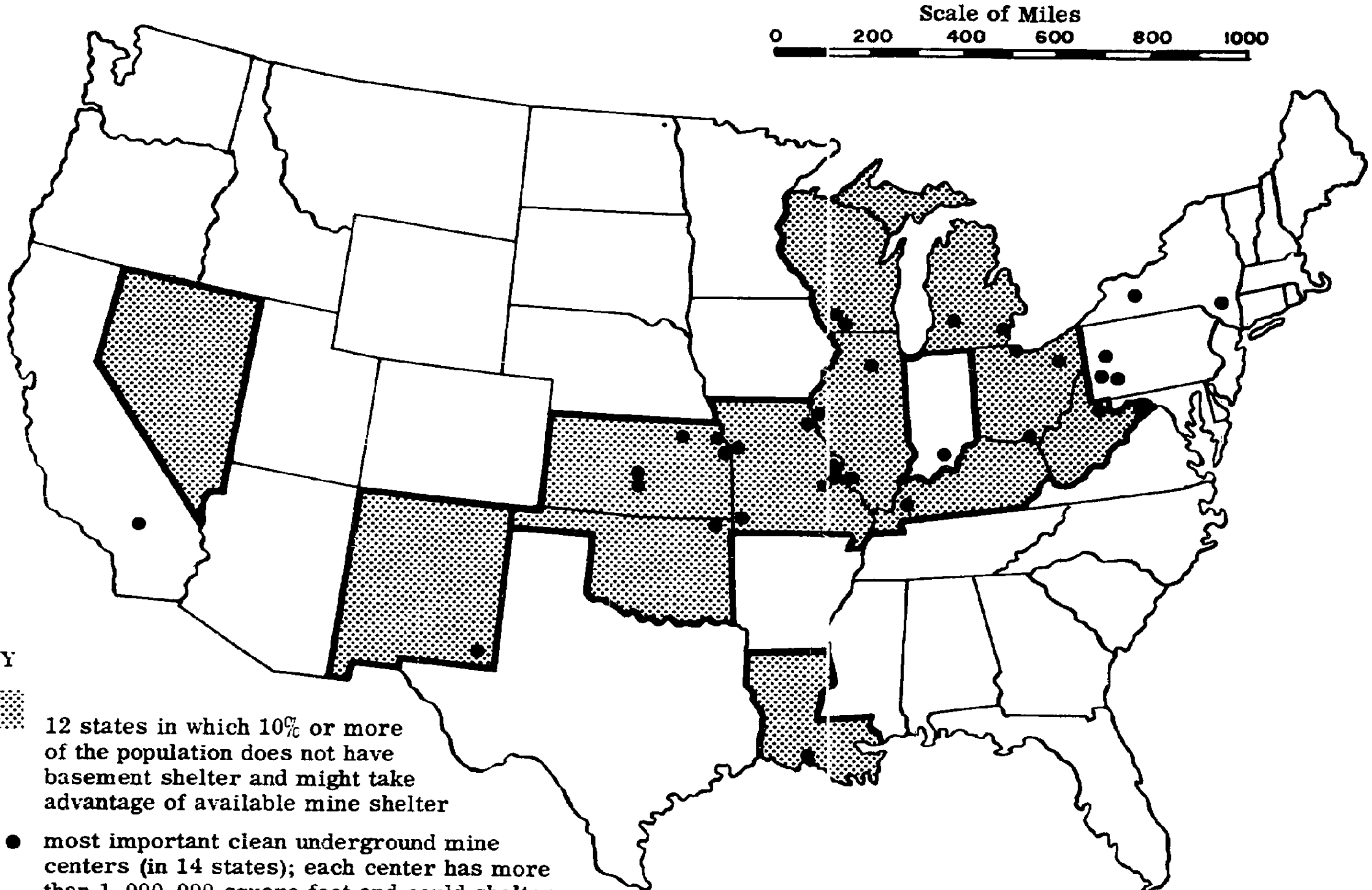
The figures in the preceding section were derived from Table 4.2. That table lists numbers of mines, estimated mine area, population and basement shelter for each state. There are 16 states noted specifically in which mine shelter is of importance. Their identity, location and likely capacities are shown in Figure 4.1. It should be noted that more capacity exists than could be used in the states of New York, Pennsylvania, West Virginia, Michigan, Missouri, Wisconsin, New Mexico, Oklahoma and Kansas. Evacuation across state borders may be an important tactic (if warning time is sufficient) in the Midwest and South.

The conservative estimate of the capacity likely to be used for mine shelter is summarized as follows:

OCDM Region	Number of People Likely to Use Mine Shelter
1	300,000 to 600,000
2	300,000 to 600,000
3	100,000 to 200,000
4	500,000 to 1,500,000
5	300,000 to 600,000
6	300,000 to 500,000
7	100,000 to 200,000
8	None
Total for Continental United States	1,900,000 to 4,300,000

The conditions under which 2,000,000 to 4,000,000 people of the continental United States might realistically take advantage of the theoretical 47,000,000 shelter spaces in mines are as follows:

1) Mines not otherwise occupied with military facilities, storage of materials, or industrial plants.
2) Mines and mine entrances not seriously damaged by nuclear attack or sabotage.
3) Mines near to the population needing shelter.
4) Mines entrances sufficiently large and numerous to permit large numbers of people to enter in a short period of time.
5) Mines free of dangers of obnoxious fumes and fitted with protected ventilating systems adequate for the number of people to be housed.



KEY

12 states in which 10% or more of the population does not have basement shelter and might take advantage of available mine shelter

● most important clean underground mine centers (in 14 states); each center has more than 1,000,000 square feet and could shelter more than 100,000 people; all residents, within an hour's travel time who do not have adequate basement shelter could be accommodated

Fig. 4.1 AVAILABLE MINE SHELTER (by states)

6) Mines fitted out to bunk people for two weeks at a capacity of up to one person per ten square feet (bunks at least four high).

7) Mines fitted out with sanitary and safety devices for the complement assigned.

8) Mines stocked with water (if not naturally available underground), food, medical supplies and fuel (if heating is essential).

9) Population is organized to enter the mines in a time period that is safe considering the likely or actual radioactive fallout.

10) Mines are managed by suitable monitors.

CHAPTER 5

CONSTRUCTION OF A MINIMUM-TYPE IMPROVISED BASEMENT SHELTER

5.1 INTRODUCTION AND OBJECTIVES

As was stated in Chapter 1 of this report, a shelter factor of 100 against fallout radiation is believed to be a realistic minimum for the populace in those areas where the highest levels of fallout might occur as a result of a full scale nuclear attack on both our military and industrial potential. Although in the larger cities and towns (of at least 50,000 population), the basements and perhaps even some of the upper floors of large multi-story public and private buildings may offer considerable shelter space with a factor of 100 or more against fallout radiation, most of the smaller cities and towns are not estimated to have adequate communal shelter potential for more than a small percentage of their residents.* Hence, it appears that the best low-cost shelter tactic for the millions of people living in the suburbs in those areas of the United States where basements are prevalent, is to make use of their own home basements. These basements on the average offer only a factor of about 20 against fallout radiation; therefore a factor of five improvement is necessary to bring the shelter factor for the shelter area selected up to the minimum suggested figure of 100.

The Office of Civil and Defense Mobilization has prepared a booklet entitled "The Family Fallout Shelter" (June, 1959) which gives detailed design and construction information for building several types of fallout shelters on the individual's premises. To date, more than a million copies of this booklet have been distributed to interested citizens all over the country. The lowest cost shelter described is a basement solid-concrete, block shelter which can be built for a materials' cost of $150 to $200, and is suggested as a "do-it-yourself" project. There is no doubt that a large number of American families could afford the $150 to $200 without having to make any important sacrifices in their normal schedule of activities. Whether they would in fact spend this amount of money, however, depends on how highly they are motivated to provide this <u>insurance</u> for themselves. In addition, it may well mean giving up valuable space in the basement which is either already being used for other purposes, or for which plans have been made — such as making a finished room for the children — although in some situations a dual purpose use can be incorporated There is also the problem of construction. To be

* See Chapter 6

sure, the seasoned "do-it-yourselfer" will generally be willing to tackle most any job whether he has previously done another one similar to it or not, but putting up a permanent concrete block shelter is probably a more ambitious undertaking than the great majority of homeowners have ever run into before.

These three potential deterrents — cost, space, and construction — to building a basement concrete block shelter prompted the improvised home basement fallout shelter study reported in the following sections of this chapter. Specifically, the objectives of this study were:

1. To design and construct a family-size, sit-down-type, fallout shelter in the corner of an average home basement.

2. To determine the realistic minimum material costs and minimum time required to assemble the shelter.

3. To determine whether this type of shelter could be built in the minimum time interval (roughly one hour) between H hour and the time of arrival of significant fallout outside the more immediate blast and thermal areas, if the materials were properly stored along the basement walls out from the corner selected for the shelter area.

Section 5.2 discusses the basic materials considered for the mass shielding and shelter support, the materials finally selected, and the costs involved. Section 5.3 describes the method and technique of constructing the improvised sandbag shelter, the time for construction, and the various dimensions, loads, and stresses.

Section 5.4 presents the results of an experimental test to determine the shelter factor provided by the structure to both Cobalt-60 and Iridium-192 gamma radiation, while Section 5.5 describes two simulated occupancy tests to determine the probable temperature rise and build-up of carbon dioxide over a two-day period. Section 5.6 discusses general habitability considerations and suggests a possible time schedule for excursions out of shelter starting at 48 hours after the attack.

In Section 5.7, a structural comparison is made between the cubical type of shelter described above and a lean-to type of shelter which has been suggested by others as having certain possible advantages. Finally, the conclusions relating to this improvised basement fallout shelter are presented in Section 5.8.

5.2 MATERIALS AND COSTS

For a rectangular shelter built into the corner of the basement, the lowest cost for any given mass shielding material per cubic foot of shelter volume occurs when the floor area is a square and the height is equal to one side, forming a cube. If we allow 70 $ft.^3$ per person for a family of five — a total volume of 350 $ft.^3$ — this corresponds to a cube 7 feet on a side, and provides 10 $ft.^2$ of floor space per person. Actually, the ceiling height of most home basements would automatically limit the inside shelter height to a maximum of about 6 feet. In order to keep the construction as simple as possible, however, it was decided to lower the inside height to 4 1/2 feet and increase the floor area from 50 to about 75 $ft.^2$ (15 $ft.^2$ per person). This, of course, would not allow adults to stand erect inside the shelter, but it was felt that the psychological advantage of being able to stand erect was less important than the degree of simplification in shelter construction afforded by lowering the ceiling height for a minimum-cost home basement shelter designed as a do-it-yourself project, and which could be put up in the shortest possible time. The additional cost of mass shielding and construction materials (for a given shelter volume) turns out to be only 15% more than would be required for a shelter with a 6-foot ceiling. For the actual sandbag shelter constructed, this "additional" cost is not meaningful since the simple design adopted would not allow increasing the height with safety to 6 feet without additional support members.

The prime objective in selecting the mass shielding material to provide an additional shelter factor of 5 over the existing factor of 20 assumed to exist in the corner of a home basement, was low cost consistent with ease of construction and long life. Two materials which might frequently be available at essentially no cost are paper (old newspapers, magazines, books, etc.) and water. Paper, however, is hygroscopic, bulky and a distinct fire hazard. An effort was made to determine if fireproof and watertight bags could be obtained in which to place newspapers, but bag manufacturers stated that no such bag is available, and if it were, it would be expensive. Water has the distinct advantage that it can be used for drinking or other purposes when the need for shelter diminishes; however, no suitable low-cost container could be found which would allow for convenient stacking to make the shelter walls. One big problem seems to be that water tends to rust through any common metal container if left standing in it for a period of a year or more

Having thus eliminated these two materials from consideration, a list of five common building materials was drawn up and a comparison made of the thicknesses and costs required to give an additional shelter factor of 5 in the basement of the average house. This comparison is presented in Table 5.1. The net shelter volume was taken to be 350 cubic feet with inside dimensions of about 8'9" x 8'9" x 4'7". Earth and sand are seen to be the two least expensive media which when bagged in high quality paper-asphalt-lined burlap bags, with 60 pounds per bag, result in a total cost of $35. The equivalent cost of mass shielding with used bricks is about $75, while that for wood or concrete blocks is about $100. Wood has the advantage of being a potential source of heat as the need for shelter diminishes. Also, in the more rural areas, many people either have a supply of firewood (or scrap lumber) on hand at all times for which they have paid little or nothing, or can get it from nearby woodlands at little or no cost. Firewood has the disadvantage of being bulky, requires a thickness of 25 inches, and is not easily "formed" into sturdy walls. Concrete blocks without doubt offer the neatest and most compact solution, but costwise they cannot compete with sand.

TABLE 5.1

COMPARISON OF THICKNESS AND COST OF COMMON SHIELDING MATERIALS REQUIRED TO GIVE ADDITIONAL SHELTER FACTOR OF 5 IN BASEMENT OF AVERAGE HOUSE

Material	Required Thickness (inches)	Size of Basic Unit	No. of Units Required	Weight Per Unit (lbs.)	Cost Per Unit(1) (dollars)	Total Cost (dollars)
1. Wood (birch, elm, maple, oak)	25	8'x4'x4'	3 cords	----	$35.00	$105
2. Earth (loose)	13	60 lb. bag	235	60	0.138(2)	33
3. Sand (dry)	10	60 lb. bag	235	60	0.148(2)	35
4. Brick (common)	9	2"x4"x8"	3300	4.5	0.023(3)	76
5. Solid Concrete Block	7.5	4"x8"x16"	380	44	0.25	95

(1) Delivered price in the Boston, Mass. area.
(2) Cost of high quality used bag is 10 cents. Ordinary fill costs $1.25 per ton, while unwashed sand costs about $1.60 per ton.
(3) Used bricks.

After analyzing the information in Table 5.1, it was decided that a sandbag shelter offered the required protection for the lowest cost consistent with good design. The only other material cost besides the sand and bags is enough lumber to form the roof and other supports to sustain the sand load. Table 5.2 lists the material costs for the sandbag shelter actually constructed.

TABLE 5.2

MATERIAL COSTS FOR HOME BASEMENT SANDBAG SHELTER

Material	Quantity	Cost/Unit*	Amount
1. Used burlap bags** (16"x27") (lined with paper asphalt)	235	$ .10/bag	$23.50
2. Unwashed sand (delivered)	7 tons	1.60/ton	11.20
3. Western hemlock, utility grade lumber (2"x10"x10')	15 pieces (250 bd. ft.)	.11/bd. ft.	27.50
		Total	$62.20

* Recent price in the Boston, Mass. area. (These prices will of course vary throughout the country.)
** These bags were originally used to ship popcorn.

The type of sandbag used for this shelter is in limited supply as a used item. However, if made available in civil defense quantities, it is believed that these bags could be manufactured to sell for about $0.10 per bag. There are many types of burlap bags available in this general price range though slightly more expensive. One of these is the standard gunny sack (18" x 28") used in large numbers by the Army for general purposes. This sack sells for $0.15. The loose weave of the gunny sack is a disadvantage because it tends to leak sand. A main advantage of the gunny sack and the lined bag actually used in the minimum shelter, however, is that according to the bag suppliers, they will last for at least five years filled with dry sand and stored in a reasonably dry area. The western hemlock utility grade lumber was chosen because of its general availability and low cost relative to its load-carrying ability.

5.3 CONSTRUCTION PROCEDURE

5.31 Filling and Storing the Sandbags and Wood Planks

The first step is to fill the 235 bags with about 60 pounds of dry sand each. The seven-ton pile of sand is shown in Figure 5.1 as it was delivered from the truck. The pile is roughly 6 feet by 5 feet by 4 feet high. A convenient average rate for filling bags turned out to be about 20 bags per man-hour. This includes, however, the time to tie the filled bags with either baling wire or ordinary string, and store them properly. The bags were actually filled outside and then placed in the basement by putting them through a basement window and sliding them down a ramp consisting of two of the 2" x 10" x 10' planks used later for the shelter roof. Figure 5.2 shows the bags in the process of being filled, while Figure 5.3 shows the filled bags placed outside the basement window ready to be sent down the ramp (see Figure 5.4). The bags are then stored along the basement walls out from the corner as can be seen in Figure 5.4.

The fifteen 2" x 10" x 10' planks can be stored at any convenient spot in the basement. One useful storage scheme is to make temporary shelves out of them using bricks to separate each shelf by the desired distance as shown schematically in Figure 5.5. Two of the planks should be sawed in half to form four 5-foot sections. One of these sections is used as the cornerpost support for the roof. Two are used as midsupports (see Figure 5.6) for the plank serving as an end support for the other twelve planks which actually form the roof. The last 5-foot section is placed over the shelter entrance.

5.32 Setting Up the Shelter

First the outside shelter dimensions of 10' by 10' are marked on the cellar floor and the sandbags making up the two walls of sand are placed along these two lines. Figure 5.6 shows a sketch of the first wall in the process of construction. Each wall is 12 bags high and 6 bags wide for a total of 72 bags. The bag is placed so that its long dimension is perpendicular to the wall. Note that the bags are stacked directly on top of one another rather than interleaved. This was done solely for simplicity and neatness after it was determined that the wall built in this way had satisfactory strength and stability (after the roof was completed) and the total "pin-hole" areas through which light or air could pass did not noticeably affect the over-all shelter factor provided by the structure.

Fig. 5.1 6–1/2 ton pile of sand for sandbag shelter

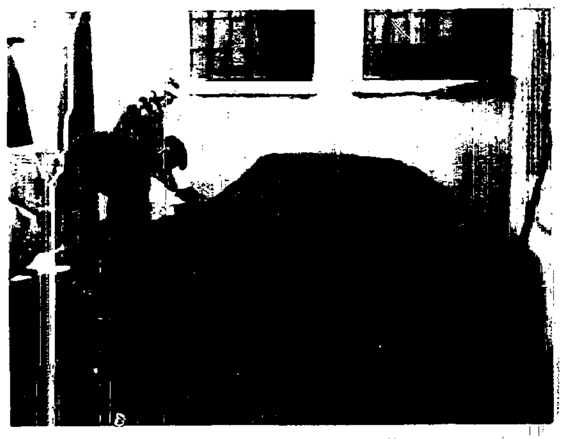


Fig. 5.2 Filling sandbags

Fig. 5.3 Filled bags ready to be put through basement window

Fig. 5.4 Bag sliding down ramp into basement

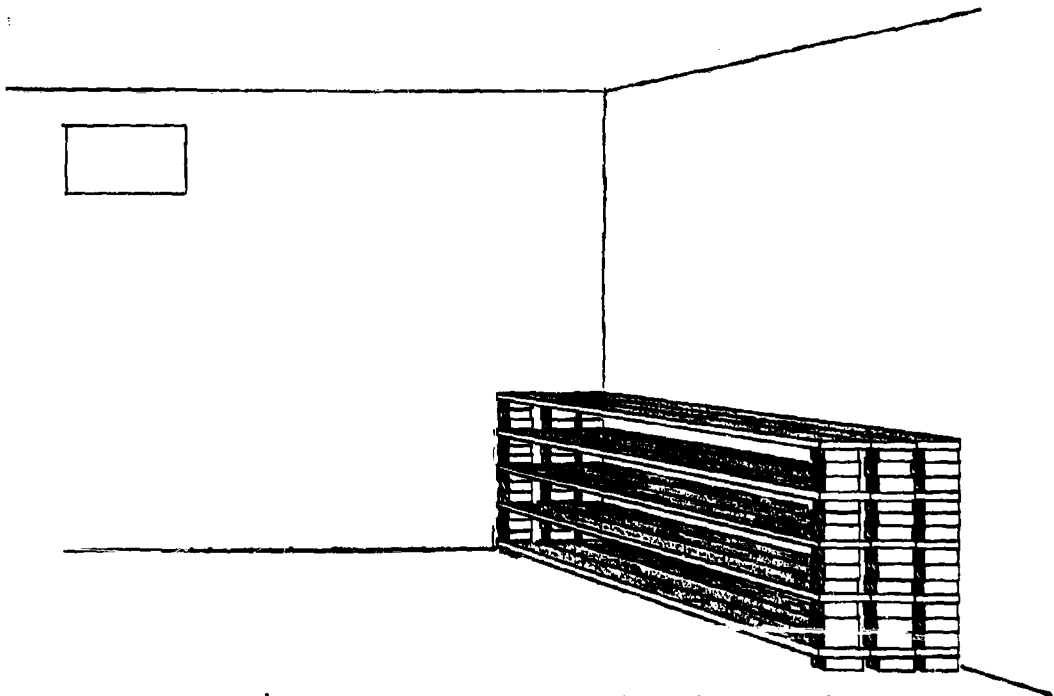


Fig. 5.5 Storing Shelter Planks in the Form of Temporary Shelving

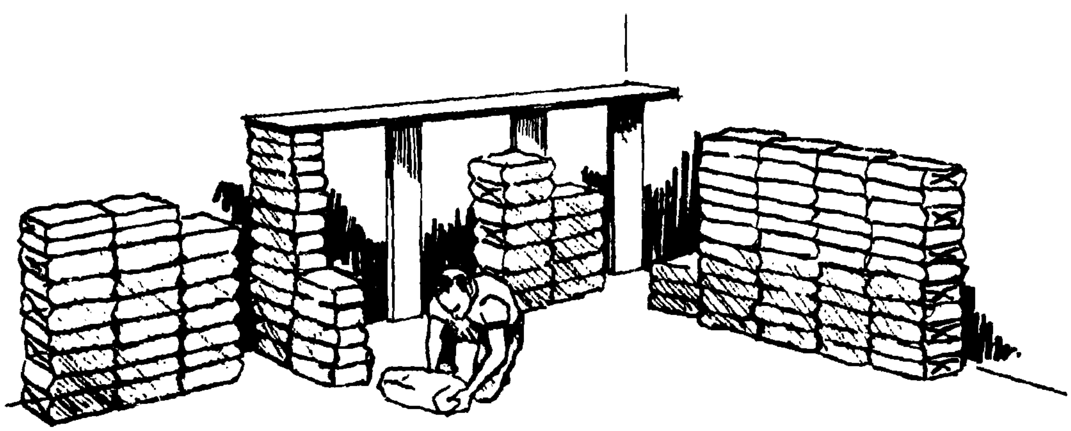


Fig. 5.6 First Wall of Improvised Sandbag Shelter in the Process of Construction

Figure 5.7 shows the completed walls and the roof support planks including the 5-foot post and midsupports, and the two parallel planks about 9 feet apart. The shelter entrance width is about 18 inches. Figure 5.8 shows the method of constructing the roof. Two planks are placed over the support planks as shown, and a layer of sandbags laid on the planks. Two more planks are then put in position and the process repeated until the 12 planks are in place and the roof covered with six rows of nine bags each. The remaining 35 to 40 bags are placed more or less randomly over the roof to give the required average thickness. A front view of the completed shelter is shown in Figure 5.9. Note that the maze entrance consists of a column of bags set in at about 45 degrees to the shelter wall. The maze does allow a narrow beam of radiation to enter the shelter, but this beam must then scatter off the basement wall inside the shelter before contributing to the dose rate over most of the shelter volume. A radiation experiment performed on the shelter indicated that this contribution is not important.

The approximate final dimensions of the completed shelter were as follows:

1. Outside dimensions: 10' x 10' x 5'8"
2. Inside dimensions: 8'9" x 8'9" x 4'7"
3. Volume: 350 cubic feet
4. Effective wall thickness: 11" (sand)
5. Effective roof thickness: 8" (sand)

5.33 Beam Stresses Due to Roof Load

The maximum recommended stress for western hemlock beams (utility grade) when used for permanent structures is 1200 lb./in.^{2}. The total roof weight of 5460 lb. (i.e., 91 bags at 60 lb./bag) is supported by 12 planks, or 450 lb. for each of the 12 members. The effective span length is about 8 1/2 feet, which corresponds to a load of 53 lb./ft. The formula for stress in rectangular beams supported at both ends is given as:

$$S = \frac{9wl^2}{bh^2} = \frac{(9)(53)(8.5)^2}{(9.75)(1.75)^2} = 1150 \text{ lb./in.}^2 \qquad (5.1)$$

where:
- S = stress in beam in pounds per square inch
- w = load per unit length of beam = 53 lb./ft.
- l = length of span = 8 1/2 feet
- b = beam width = 9 3/4 inches } 2" x 10" plank
- h = beam thickness = 1 3/4 inches }

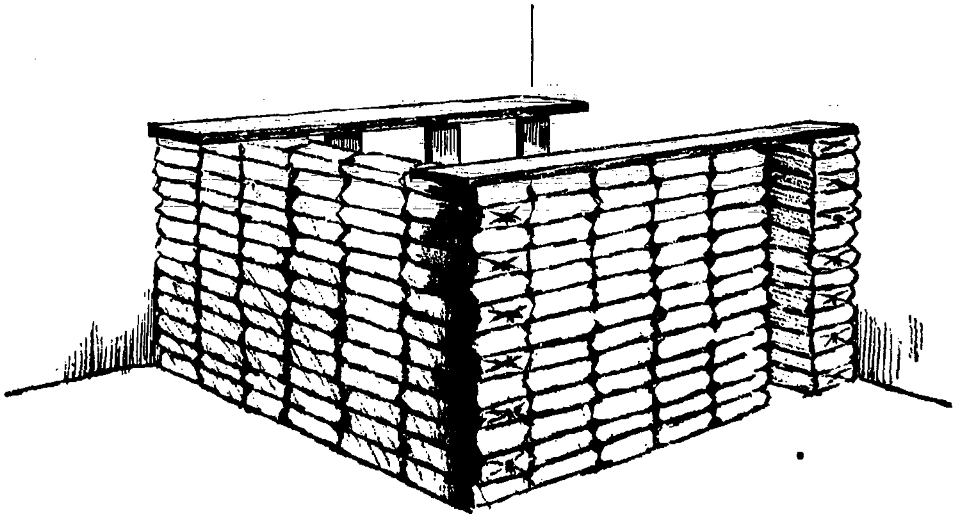


Fig. 5.7 Sandbag Shelter Showing Completed Walls and Roof Supports

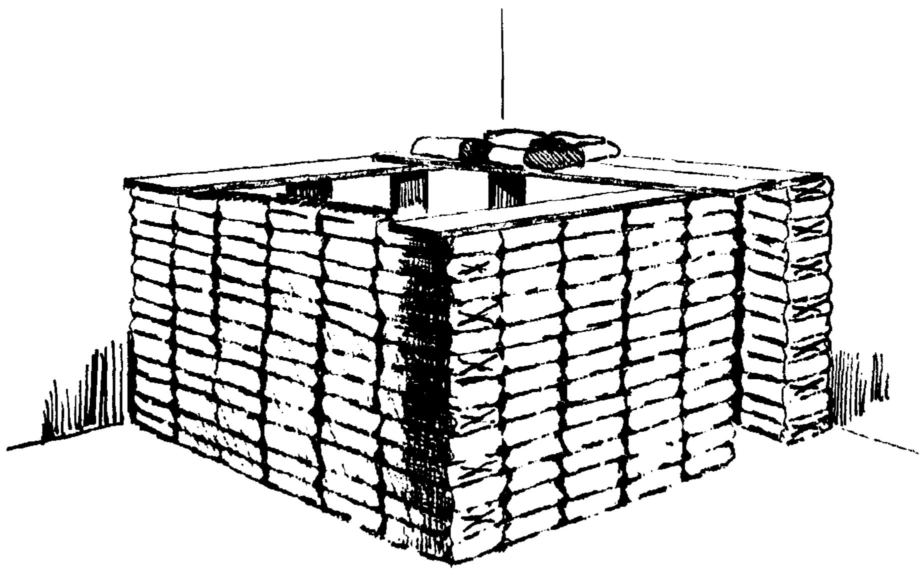


Fig. 5.8 Sandbag Shelter Showing Method of Constructing the Roof

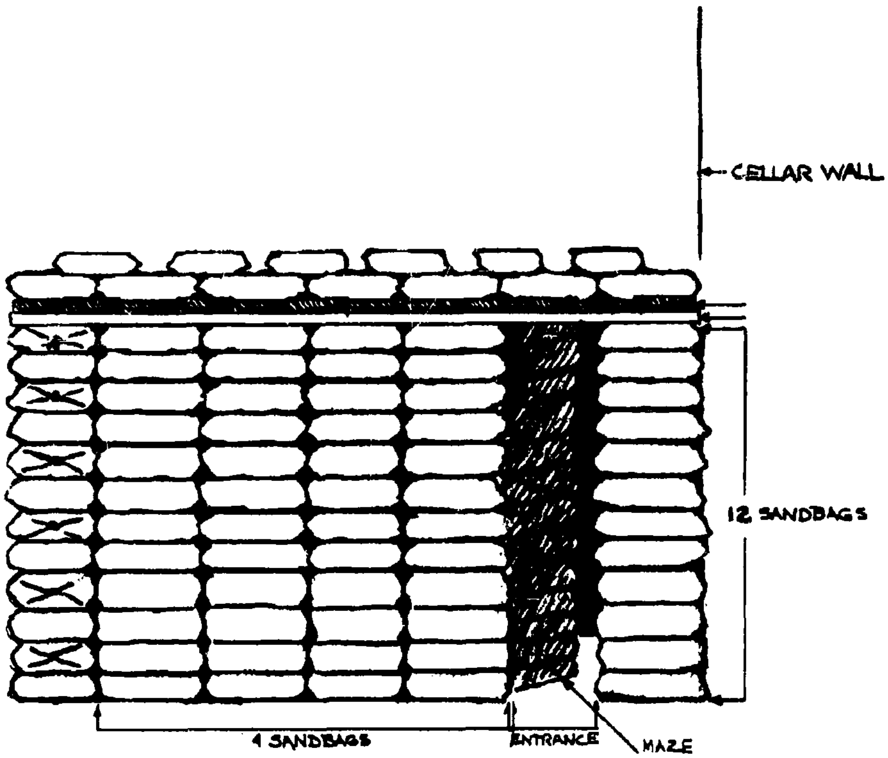


Fig. 5.9 Front View of Completed Sandbag Shelter

Thus we see that the 12 western hemlock beams forming the roof are stressed to just below the maximum recommended stress for permanent structures.

The maximum deflection of the beams is given by:

$$y = \frac{5wl^4}{384EI} \qquad (5.2)$$

where: y = maximum deflection in inches

$E = 1.4 \times 10^6$ lb./in.^{2}

$I = \frac{bh^3}{12}$ = moment of inertia

When numerical values are substitued in this equation, the maximum beam deflection is found to be just over one inch. Subsequent measurement on the actual shelter verified this calculation for the maximum deflection.

The beam which supports the 12 roof members on one side must support half the total roof load or 2,730 lb. This beam, however, is supported at the 1/3 and 2/3 points along its length as shown in Figure 5.6, which cuts the span length to approximately 3 feet. The load per unit length is:

$$w = \frac{2,730 \text{ lb.}}{9 \text{ ft.}} = 303 \text{ lb./ft.}$$

Hence, the maximum stress in this beam is found from equation (5.1) to be:

$$S = \frac{9wl^2}{bh^2} = \frac{(9)(303)(3)^2}{(9.75)(1.75)^2} = 820 \text{ lb./in.}^2$$

which is well below the maximum recommended value of 1200 lb./in.^{2}.

In summary, the roof load and beam stresses are as follows:

1.	Total weight of roof:	5,460 lbs.
2.	Effective roof load on hemlock beams:	63 lbs./ft.^{2}
3.	Maximum stress in hemlock roof beams:	1,150 lbs./in.^{2}
4.	Maximum stress in roof support beams:	820 lbs./in.^{2}
5.	Maximum recommended stress for western hemlock (permanent structures):	1,200 lbs./in.^{2}
6.	Maximum beam deflection:	1 inch

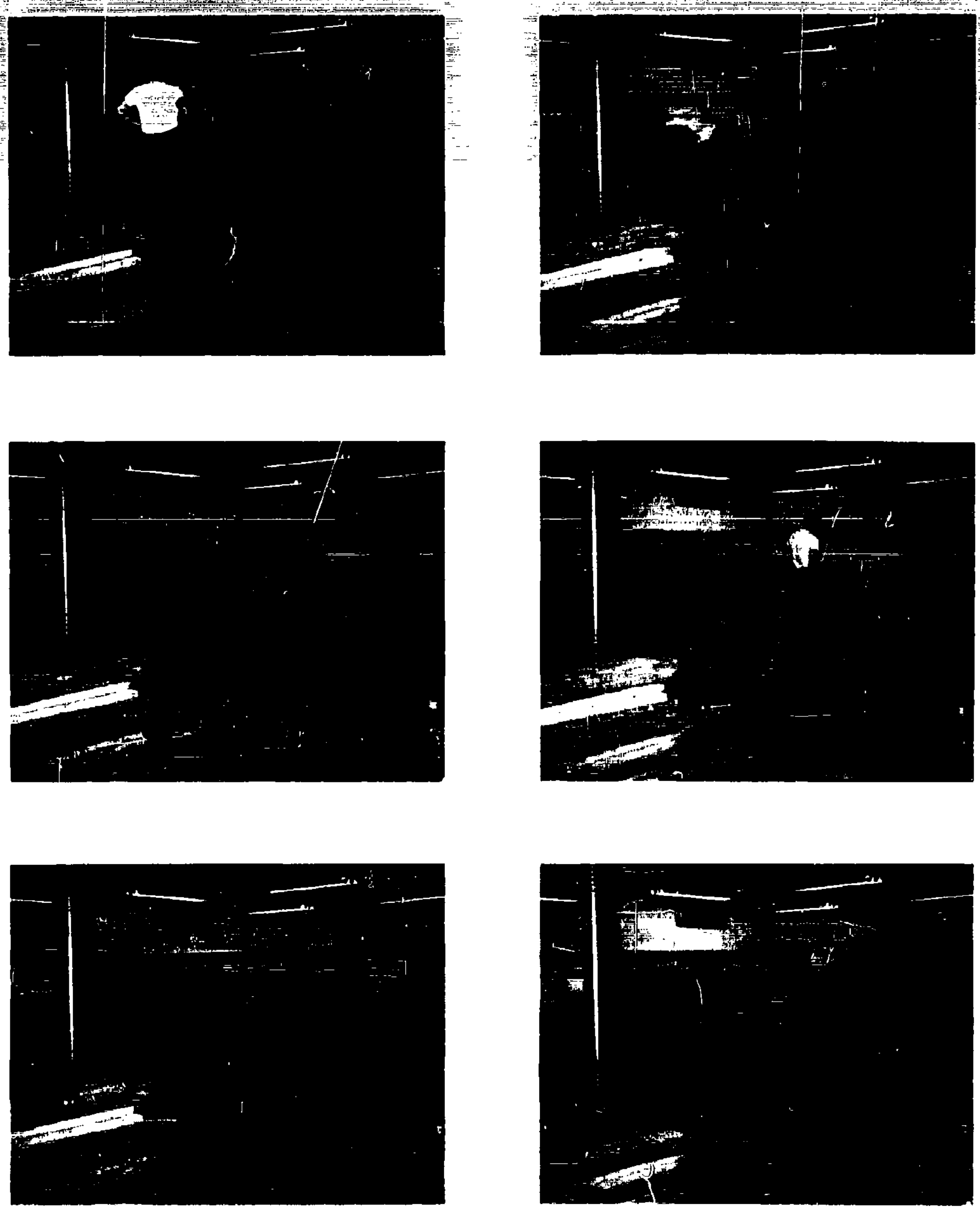


Fig. 5.10 PHOTOS SHOWING ACTUAL PROGRESS IN BUILDING SHELTER AT 5-MINUTE INTERVALS. Total Construction Time Was 55 Minutes for One Man.

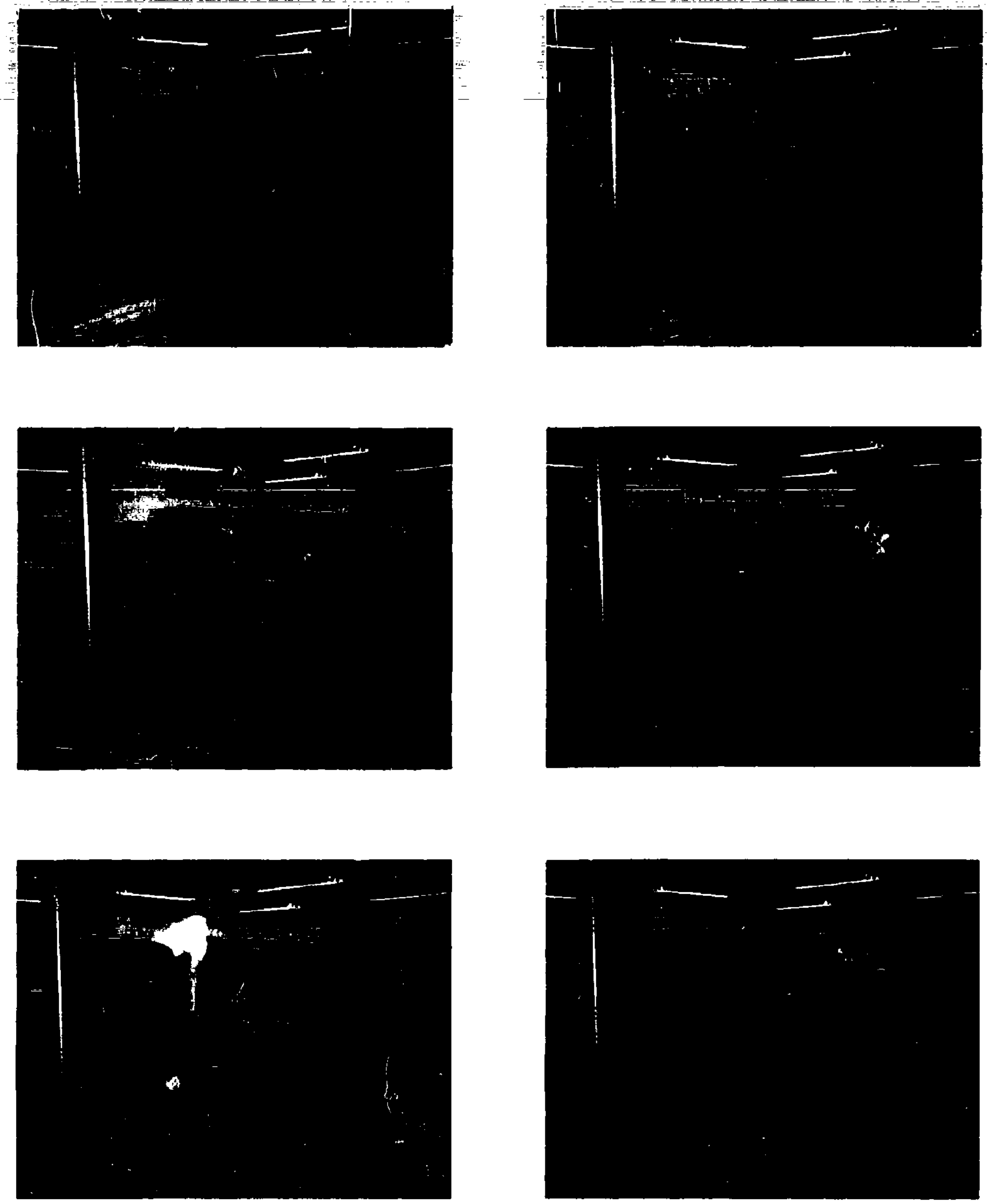


Fig. 5.10 (Cont'd) **PHOTOS SHOWING ACTUAL PROGRESS IN BUILDING SHELTER AT 5-MINUTE INTERVALS. Total Construction Time Was 55 Minutes for One Man.**

5.34 Time Required to Assemble Shelter

One of the objectives of this sandbag shelter study was to determine whether this type of shelter could be built by one person in the minimum time interval estimated at roughly one hour between H hour and the time of arrival of dangerous fallout levels outside the more immediate blast and thermal areas, if the materials were properly stored along the basement walls.

To determine the minimum construction time, the assembled shelter was dismantled and all the sandbags and roof support members carefully stacked along the walls out from the corner. One man then proceeded to construct the shelter with pictures taken at 5-minute intervals to show the rate of progress. The construction was completed in 55 minutes without difficulty. Figure 5.10 shows the actual progress after each 5-minute interval. Note that the walls were put up in just 20 minutes, while the roof took 35 minutes.

Admittedly, fatigue started to set in toward the end, and the effect on the lower back muscles was noticeable for the next 24 hours or so. By 36 hours, however, the stiffness had all disappeared. The sandbags actually used in this test were filled to an average weight of about 70 lbs., rather than 60 lbs. as recommended here. The 70-lb. weight was all right for the walls where the bags didn't have to be lifted very high, but was a definite handicap in building the roof. In those instances where a woman might have to assemble this type of shelter, the weight of the bags should probably be reduced to no more than 50 pounds.

5.4 ESTIMATE OF SHELTER PROTECTION FACTOR

A radiation experiment was performed to estimate the degree of shelter protection offered by the sandbag shelter against radiation sources in the basement. Cobalt-60 and Iridium-192 were selected as the radioactive sources to be used because their gamma ray energies bracket those of mixed fission products.

A 0.355 curie Cobalt-60 source was placed in the center of the shelter and radiation intensity measurements made at more than 400 grid points on the walls and roof of the shelter after reciprocity* was checked and found to hold. The experiment was then repeated using a 0.70 curie Iridium-192 source. The totals of all measured intensities on each shelter wall and the roof for each experiment were then summed and compared against the corresponding theoretical intensities that would have resulted if the shelter weren't there. The ratio of the theoretical to the measured intensities gives the estimated protection factor for the shelter. The results of this experiment are summarized in Table 5.3. From the table, the shelter is seen to offer an over-all shelter factor of 4.0 against Cobalt-60 radiation and 7.5 against Iridium-192. Neither the distribution of gamma ray energies in a basement nor the effective source distribution of radiation in the basement due to fallout is well established; however, it is believed that the energies of importance probably lie somewhere between those of Cobalt-60 and Iridium-192, and for lack of a better assumption, the source distribution is generally taken to be isotropic. If these assumptions are realistic, then the sandbag shelter as described in this chapter should conservatively offer an additional protection factor of five over that which already exists in the basement.

* Reciprocity is said to hold when the position of the source and detector can be interchanged without altering the detector reading.

TABLE 5.3

MEASURED PROTECTION FACTORS FOR ROOF AND WALLS OF SANDBAG SHELTER AGAINST COBALT-60 AND IRIDIUM-192 RADIATION SOURCES IN THE BASEMENT

Protection against Cobalt-60 Radiation

Category	Total of All Theoretical Intensities (r/hr)	Total of All Measured Intensities (r/hr)	Protection Factor (Ratio of Theoretical to Measured Intensities)
Roof	67.22	17.59	3.8
Wall with Shelter Entrance	12.43	3.01	4.1
Wall without Shelter Entrance	12.43	2.73	4.6
Total for Both Walls	24.86	5.74	4.3
Total for Shelter	92.08	23.33	4.0

Protection against Iridium-192 Radiation

Category	Total of All Theoretical Intensities (r/hr)	Total of All Measured Intensities (r/hr)	Protection Factor (Ratio of Theoretical to Measured Intensities)
Roof	54.00	7.07	7.6
Wall with Shelter Entrance	9.98	1.77	5.6
Wall without Shelter Entrance	9.98	1.04	9.6
Total for Both Walls	19.96	2.81	7.1
Total for Shelter	73.96	9.89	7.5

5.5 SIMULATED OCCUPANCY TESTS

In order to get certain information on the physiological environment of this "minimum" sandbag shelter, two simulated human occupancy tests were made:

1. A test to determine what the temperature rise inside would be due to the body heat radiated by the shelter occupants.

2. A test to determine the amount of build-up in the carbon dioxide content of the air inside the shelter, when CO_2 was introduced at the rate at which it would be exhaled by the shelter occupants. (This would give a measure of the degree of air circulation from the basement into the shelter.)

5.51 Temperature Rise in the Shelter

It has been determined that an average adult under sedentary conditions radiates about 200 BTU's per hour if the ambient temperature is $75^{\circ}F$. The corresponding figure for a child is 150 BTU's per hour. These rates decrease as the temperature increases, falling to zero at about $100^{\circ}F$. About 200 BTU's are also removed from the body by evaporation from the skin when the relative humidity is about 60%, the amount of evaporation, of course, dropping to zero when the relative humidity reaches 100%.

To determine the expected temperature rise in the shelter over a two-day period due to the heat radiated by a family composed of two adults and two children, 700 BTU's of heat were introduced by means of ordinary incandescent light bulbs. After 24 hours the temperature at the ceiling of the shelter had stabilized 6° above the ambient basement temperature of $74^{\circ}F$. At the center of the shelter it was 5° above ambient.

From this test it would appear that temperature rise is not likely to be a serious problem for this type of shelter.

5.52 Air Circulation Study

One possible limitation to the livability of the home basement sandbag shelter is the pollution of the air in the shelter by the occupants. The objective of this study was to estimate the extent of this hazard over a 48-hour period by introducing carbon dioxide at the rate it would be exhaled by a family of four.

The average person, under sedentary conditions, exhales carbon dioxide at the rate of 18 liters per hour.* Thus to simulate a family of four, CO_2 was introduced into the shelter (from a 50-pound tank) at the rate of 72 liters per hour, and the CO_2 concentration monitored with a standard "Fyrite"** instrument over a two-day period. The instrument has a maximum scale reading of 20% and can be used for accurate determinations down to 1/2%.

If no exchange of air were to take place, the volume of CO_2 in the shelter would represent 35% of the shelter volume. The result of this test, however, was that the CO_2 level never reached the minimum reliable instrument reading of 1/2% over the two-day period, indicating that there was ample air circulation between the basement and the shelter. (It is interesting to note that the maximum allowable CO_2 concentration for public buildings is listed as 1/2% in the 1956 edition of "Heating, Ventilating and Air Conditioning Guide".)

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* Roger Williams, "Textbook of Biochemistry".

** This instrument is used widely by home oil burner servicemen to determine combustion efficiencies.

5.6 HABITABILITY CONSIDERATIONS AND TIME SCHEDULING FOR EXCURSIONS OUT OF SHELTER

Although no human occupancy tests were conducted with the sandbag shelter, considerable thought was given to the distinction between those essential items and functions which should be provided or carried out in the shelter at the start and those items which could be taken from or carried out in other parts of the house as needed after the second day in accordance with a realistic excursion schedule which would allow for increasing time spent out of shelter each day.

5.61 Essential Shelter Items*

The first item considered for the shelter was sleeping facilities. Either standard folding cots (16" high, 27" wide and 75 1/2" long), or air mattresses appeared to be satisfactory. The folding cots, which can be purchased new for about $4.50 per cot, were actually tried out and found to be quite comfortable. A potential disadvantage of the air mattress is the chance of its springing a leak which might be difficult to fix on the spot.

It was felt that a good strong light source suitable for reading without eye strain in the shelter should be provided. Candles are perhaps the least expensive source of light available and can be readily stocked. The illumination from the candle can be considerably enhanced by using reflectors made out of any "silvery" material such as aluminum foil; also, painting the ceiling white will increase the illumination. A more elegant source of light would be a gas lantern (such as Coleman's) which can be purchased for $10 to $12, provides enough light for all shelter activities, and will operate for 15 to 20 hours on a pint of non-leaded gas. Hence, a gallon of gas would operate the lamp for 10 to 12 hours per day for 2 weeks! A flashlight or two should, of course, in any case, be available for emergencies.

Enough food and water should be provided in the shelter for at least two days. After this time, the excursion schedule (to be described later) will allow for getting food and water from the kitchen or other parts of the house. It is most important, however, to have at least a two-weeks supply of canned or non-refrigerated food in the house. If water is derived from open reservoirs, it may well be contaminated. Although it is most unlikely that this contamination would cause sickness at early times due to drinking, water

* Not intended to be an all-inclusive list.

in the hot water tank would be free from any contamination and should be used for consumption if there is any question concerning the safety of the public supply. Cooking should probably be kept to a minimum, but a camp stove (such as Sterno cookers, Coleman stoves, etc.) would be a very desirable addition to the shelter for use if the family so desired.

Although clearly not essential for physical survival, recreation facilities may have a profound morale effect on the shelter inhabitants. Books (including song books), games, and items conducive to a variety of creative or productive activities should be included in the shelter.

Finally, two indispensible shelter items are a battery-powered transistorized radio and a radiation detection instrument. A variety of one-transistor, "pocket" radios using one penlight cell can be purchased for about $5, which are capable of picking up standard broadcast radio stations at distances up to at least 30 miles. A radiation detection instrument described in report No. TO-B-60-21 entitled "The Electroscope -- A Home-Made Radiation Detection Instrument for Home Use" prepared for OCDM and dated May 15, 1960, can be assembled by anyone with a do-it-yourself interest for a materials cost of less than $1. This instrument, which gives an indication of the radiation intensity, can be used to determine when it is safe to come out of shelter and for how long. A citizens' instrument "package" is now commercially available through Bendix Corporation, 3130 Wasson Road, Cincinnati, Ohio. The three-instrument package is approved by OCDM and sells for $20. To accurately determine radiation intensity, only two of the three instruments are required, and these two can be bought for $15. Although the third instrument, a 600 r high-range dosimeter (cost, $7), is intended to be used to keep an accurate and reliable record of the citizen's total radiation exposure, it can be used by itself (and a watch) in emergency to estimate the outside average radiation intensity level over a short period of time. A rough indication of the dose rate in the shelter can then be found by dividing by the estimated shelter factor.

5.62 Time Scheduling for Excursions out of Shelter

Since all radiation exposure is assumed to be harmful to humans, one should do everything possible to minimize his dose due to fallout. The longer one plans to stay in shelter, however, the more elaborate and costly the shelter and its provisions will have to be, and the slower will be the rate at which

recovery operations can proceed. For example, the problems of food and water supplies and the disposal of human wastes become simpler if one can plan on making even very short excursions from shelter (i.e., fractions of an hour) after two days as opposed to having to remain constantly in the shelter for two weeks. The purpose of this section is to suggest a possible schedule starting after 48 hours and continuing through the next 12 days which would allow for gradually increasing excursion times each day from an improvised basement shelter to carry out essential activities <u>even in the heaviest probable fallout areas</u>.

From Chapter 6 of report No. TO-B 60-13 entitled, "The Probable Fallout Threat over the Continental U. S." prepared for OCDM and dated 12/1/60 the heaviest fallout areas (representing 1 or 2% of the land area) outside the immediate blast zones might be expected to receive up to a 10,000 r two-day dose, while 5% of the land area might have a two-day dose of 5,000 r or greater.

The following example of a possible excursion schedule is based on the assumption of a 5,000 r two-day dose, an improvised basement shelter factor of 100, a shelter factor of 20 in the basement, and a factor of two upstairs in the house. It is further assumed that the shelter occupants might receive about 25 r in the basement during the first critical hour or so while the shelter and necessary supplies are being assembled, and that the dose rate after 48 hours will have fallen to 20 r/hr.

During the first two days the shelter occupants would receive about 45 r in the shelter, and from the third through the fourteenth day, an additional 15 r in shelter for a total of 85 r. If a maximum additional dose of 5 r per day were allowed for carrying out essential activities, this would bring the two weeks' total exposure to 150 r which, although it should be avoided if at all possible, would not be expected to result in significant incapacitation to the average adult. A daily limit of 5 r outside the improvised basement shelter could be maintained with the schedule as shown in Table 5.4. In summary, one could spend up to 30 minutes upstairs after the second day, and increase this time by about 20 minutes each day for the next twelve days (assuming no basement or outside excursions). Or, one could spend up to 15 minutes outside after the second day and increase this time by approximately 10 minutes each day over the two-week period. After the first week, one could actually spend a number of hours in the basement each day without having to curtail upstairs or outside excursion times by more than about 20%.

TABLE 5.4

EXCURSION SCHEDULE OUT OF IMPROVISED BASEMENT SHELTER IN FALLOUT AREA RECEIVING A TWO-DAY DOSE OF 5,000 ROENTGENS

TIME SPENT EACH DAY FOR 5 R ADDITIONAL DOSE

End of Day	In Basement (hours)	or	Upstairs	or	Outside	Intensity Outside at End of Day (r/hr)
2	5		30 min.		15 min.	20.0
3	8		50 min.		25 min.	12.4
4	11 1/2		70 min.		35 min.	8.8
5	15		1 1/2 hrs.		45 min.	6.8
6	18		1 3/4 hrs.		55 min.	5.6
7	22		2 1/4 hrs.		65 min.	4.6
8	all day		2 1/2 hrs.		1 1/4 hrs.	3.9
9	all day		3 hrs.		1 1/2 hrs.	3.4
10	all day		3 1/4 hrs.		1 3/4 hrs.	3.0
11	all day		3 3/4 hrs.		2 hrs.	2.7
12	all day		4 1/4 hrs.		2 hrs.	2.4
13	all day		4 1/2 hrs.		2 1/4 hrs.	2.2
14	all day		5 hrs.		2 1/2 hrs.	2.0

Some of the many possible reasons which people will feel are important enough to make excursions from shelter during the first two weeks are as follows:

1. Disposal of human waste.
2. Obtain additional food and water from elsewhere in the house.
3. Obtain items such as additional blankets for comfort, or recreation materials.
4. Attempts to contact CD authorities to get information on outside conditions, find out about the safety of relatives, friends, etc.
5. Need for fresher air.
6. Exercise.
7. Curiosity.

Since children's need for exercise is paramount, it would appear that their excursion time should be spent entirely in the basement if possible for at least the first week. This would give them the maximum time out of the shelter for a given exposure, which should, if at all possible, be kept well below the 5 r per day suggested for essential excursions. It should be noted, that the radiation hazard is substantially reduced each day for the first four days, and at the end of four days there is still a 25% "saving" to be made in waiting until the end of the fifth day to carry out any upstairs or outside task.

The excursion times listed in Table 5.4, to keep one's total dose over two weeks to 150 r, cannot be scaled directly for either higher or lower two-day dose levels. However, even in an area contaminated to a 10,000 r two-day dose level, halving the excursion times shown in the table would still not result in a two-weeks' dose of more than 200 r which is not expected to cause any significant incapacitation. Where the two-day dose level was 2500 r, the excursion schedule shown would result in a two-week dose of only 100 r.

5.7 COMPARISON WITH A LEAN-TO TYPE OF SHELTER

It has been suggested that a lean-to type of shelter might result in a more efficient use of sandbags as a shielding material than the cubic structure described in this chapter. If the same 2" x 10" x 10' planks were used for a lean-to shelter, the maximum shelter volume would result when the boards made a 45° angle with the basement wall and floor, reaching 7 feet up on the wall and 7 feet out on the floor from the wall. A calculation shows that to provide the same net shelter volume of 350 cubic feet, the lean-to must be 14 feet long which would require 17 planks (as opposed to 15 for the cubic structure), and 205 60-lb. sandbags (as against 235 bags for the previous design). Thus from the point of view of material costs, the two designs are within $1 of being a standoff.

The lean-to shelter would have the obvious advantage of allowing standing room at the basement wall end, but has a major disadvantage in that a strong support would be needed along the 14-foot length where the boards (and sandbags) meet the floor to keep the whole structure from sliding out and causing the shelter to collapse. Another possible disadvantage would be the tendency of the bags to "bunch up" near the bottom, leaving "bare" space toward the top. This condition would be particularly aggravated during the shelter construction period since the person assembling the shelter would have to walk over the lower bags in order to place the higher ones in position.

The seriousness of these construction problems can best be determined by actual experiment; however, it is our belief that the lean-to shelter would not in general be as easy to construct as the cubical structure. A possible exception might be where the width of the basement at the shelter location was just equal to the desired width of the shelter thus eliminating the problem of finding a suitable support at the floor for the planks and bags.

5.8 CONCLUSIONS

1. A family-size (i.e., 350 cu. ft.) sandbag, sit-down-type of fallout shelter can be easily constructed by the homeowner in the corner of the basement for a materials' cost of about $60.

2. This shelter, which offers a protection factor of about 100 against outside radiation levels, can be assembled in an hour by one person if the materials are properly stored along the basement walls out from the corner.

3. Normal air circulation between the shelter and basement appears to be sufficient so as not to result in any serious discomfort to the shelter occupants for the time they must spend in shelter. Likewise the shelter temperature is not expected to rise more than a few degrees above the ambient basement temperature.

4. A lean-to-type of improvised basement shelter offers no cost advantage over a cubical structure, and, in general, will not be as easy to construct.

5. Realistic excursion schedules out of an improvised basement shelter appear possible after two days even in the heaviest fallout areas.

CHAPTER 6

SHELTER POTENTIAL AND OTHER ESSENTIAL POST ATTACK RESOURCES IN AN ACTUAL SUBURBAN COMMUNITY

6.1 INTRODUCTION

Since thousands of smaller cities and towns in the United States may be isolated and have to survive for days or weeks after a nuclear attack solely on their own, it is of prime importance for each town to know exactly what its shelter potential is and what essential resources it can count on in the post attack period if it is fortunate enough not to be in the heavy blast damage area. This is perhaps most important for suburban cities and towns which are, say, 10 to 30 miles away from prime industrial or military targets. These communities would undoubtedly suffer some blast and thermal damage, but their population could likely survive the attack if adequate and sufficient fallout shelter were available together with a two-weeks supply of food and water.

A shelter factor of 100 was selected in Chapter 1 as being a realistic minimum for those areas likely to have the heaviest fallout. The average home basement provides only a factor of about 20 against the outside intensity, while in some areas, only a small percentage of the homes even have basements (see Chapter 2). Two other potential sources of good shelter in certain areas are in covered boats more than 250 yards off shore, and in mines as discussed in Chapters 3 and 4 respectively.

An attractive source of potentially good shelter is the basements and perhaps some of the upper floors of large public and private buildings where shelter factors of 100 or more frequently exist without the need of any modifications or improvements. The Office of Civil and Defense Mobilization is continuing to conduct fallout shelter surveys in some of the larger cities in the country. Surveys are now essentially completed for Tulsa, Oklahoma; Montgomery, Alabama; and Contra Costa County, California. While others either planned or proposed for completion next year include Milwaukee, Los Angeles, New York City, the State of Delaware, and Tallahassee, (Fla.). Some of the key results* of the surveys completed to date are summarized in Table 6.1.

* Data taken from a copy of a talk entitled "Fallout Shelter Survey of the Central Business District, Tulsa, Oklahoma" presented to the U.S. Civil Defense Council, Houston, Texas on October 15, 1959, by Paul H. Rogers of OCDM.

TABLE 6.1

RESULTS OF SHELTER SURVEYS IN TULSA, OKLAHOMA METROPOLITAN AREA, MONTGOMERY (CITY AND COUNTY), ALABAMA, AND CONTRA COSTA COUNTY, CALIFORNIA

Area	Population	Per Cent of Population that can be Sheltered With Shelter Factor $\geq$ 50	With Shelter Factor $\geq$ 10
Tulsa, Oklahoma Metropolitan Area	322,847	31.3	100.
Montgomery, Alabama City and County	177,000	7.6	41.0
Contra Costa County, California	265,828	4.3	9.8

The results show a serious lack of good shelter in each of the three areas surveyed, with the worst situation in Contra Costa County, California where only one-tenth of the population can theoretically be sheltered with even a shelter factor of ten or better. The fact is, however, that some good shelter does exist — in Tulsa, Oklahoma, more than 100,000 people can theoretically be accommodated with a shelter factor of 50 or more — and plans should be made now to make optimum use of this shelter space without waiting for a shelter building or improvement program. There is, however, a basic difference in the type of public and private buildings found in large metropolitan areas (100,000 population and up) as opposed to those found in the smaller cities of 10,000 to 50,000 population which account for the major part of our suburban population. These smaller cities do <u>not</u> have the large multi-story office buildings and commercial establishments common to the large cities. They do have their schools, churches, city hall, etc. which are generally of heavy wall construction, but only two or three stories high with wood rather than concrete floors. Hence, the fallout on the roof may often be the limiting factor on the degree of fallout protection they provide.

The purpose of this report is to analyze the communal shelter potential of an actual small city in the northeast to determine whether a communal shelter plan is feasible for the average suburban community in those areas where basements are generally available. Food, water, power and other essential resources were also investigated to determine whether a shortage of any one of them might loom to be a serious threat to the survival of the community in the immediate post attack period.

The community actually chosen for this study was the city of Woburn, Mass., which lies ten miles northwest of Boston, and had a 1955 population of about 26,000.* The city is located on U.S. Route 3, Mass. Highways 38 and 128, and has an area of 13 square miles. It was selected as the "typical model city" because it has:

1) A city form of government with a mayor and city council. (There are seven wards within the city which have almost equal populations and areas so that with only slight modifications, the city can conveniently be divided into seven shelter areas.)

2) Areas of both high and low population density.

3) Small, medium and large industries.

4) A wide variety of potential communal shelters including 16 churches, 13 schools, a hospital, library, city hall, armory, and varied industrial and commercial establishments.

To get an idea of the probable fallout levels (and possible blast damage) over the city, the post attack situation was studied in the light of the hypothetical combined attack described in Chapter 2 of Report No. TO-B 60-13 entitled "The Probable Threat over the Continental United States". Section 6.2 describes the radiological situation in Woburn resulting from this hypothetical attack which placed seven 5-MT weapons on military and industrial targets in the greater Boston area.

Section 6.3 presents the results of the fallout shelter survey for this "model" city. The OCDM Fallout Shelter Survey Guide (dated April 1959) was used to compute the ground and roof contribution for each building, and determine the net shelter space available. Section 6.4 summarizes the shelter problem and surveys such other essentials to survival as food, water, and power facilities.

* Estimated at about 30,000 in 1960.

6.2 THE RADIOLOGICAL SITUATION

6.21 The Attack Pattern

The shelter problem for the city of Woburn, Mass. was viewed in light of the radiological situation which resulted from the combined attack mentioned above. This attack, which put approximately 819 5-MT weapons on 159 military and 148 industrial targets in the U. S., resulted in seven 5-MT weapons being dropped in the greater Boston area which were all within a 15-mile radius of the "model" city. However, the center of Woburn was about 6 1/2 miles from the nearest "hit" and eight miles from the next two nearest bomb drops, thereby just escaping complete destruction though admittedly sustaining considerable blast and thermal damage.

The actual ground zero locations for this "local" attack pattern are listed in Table 6.2, together with their distance from the model city, the overpressure created, and an estimate of the two-day dose due to fallout.* Figure 6.1 is a map of the greater Boston area showing the assumed seven ground zero locations.

TABLE 6.2

EFFECT ON WOBURN, MASS. DUE TO SEVEN 5-MT WEAPONS DROPPED ON TARGETS IN THE GREATER BOSTON AREA

Ground Zero Location	Distance from Woburn (miles)	Overpressure at Woburn (psi)	Two-Day Dose on Woburn (roentgens)
1. Bedford, Mass. (Hanscom Air Force Base)	4 - 9	7.0 - 2.1	1300 - 800
2. Waltham - Watertown Mass.	6 - 12	3.7 - 1.4	275 - 150
3. Cambridge, Mass. (M.I.T. area)	8 - 12	2.4 - 1.4	225 - 110
4. Lowell, Mass.	12 - 15	1.4 - 1.0	300 - 90
5. Boston, Mass.	9 - 12	2.1 - 1.4	150 - 45
6. Lynn, Mass.	9 - 14	2.1 - 1.1	120 - 40
7. Dorchester, Mass.	12 - 16	1.4 - 1.0	60 - 30

* See Section 6.22 for wind selected and fallout model used.

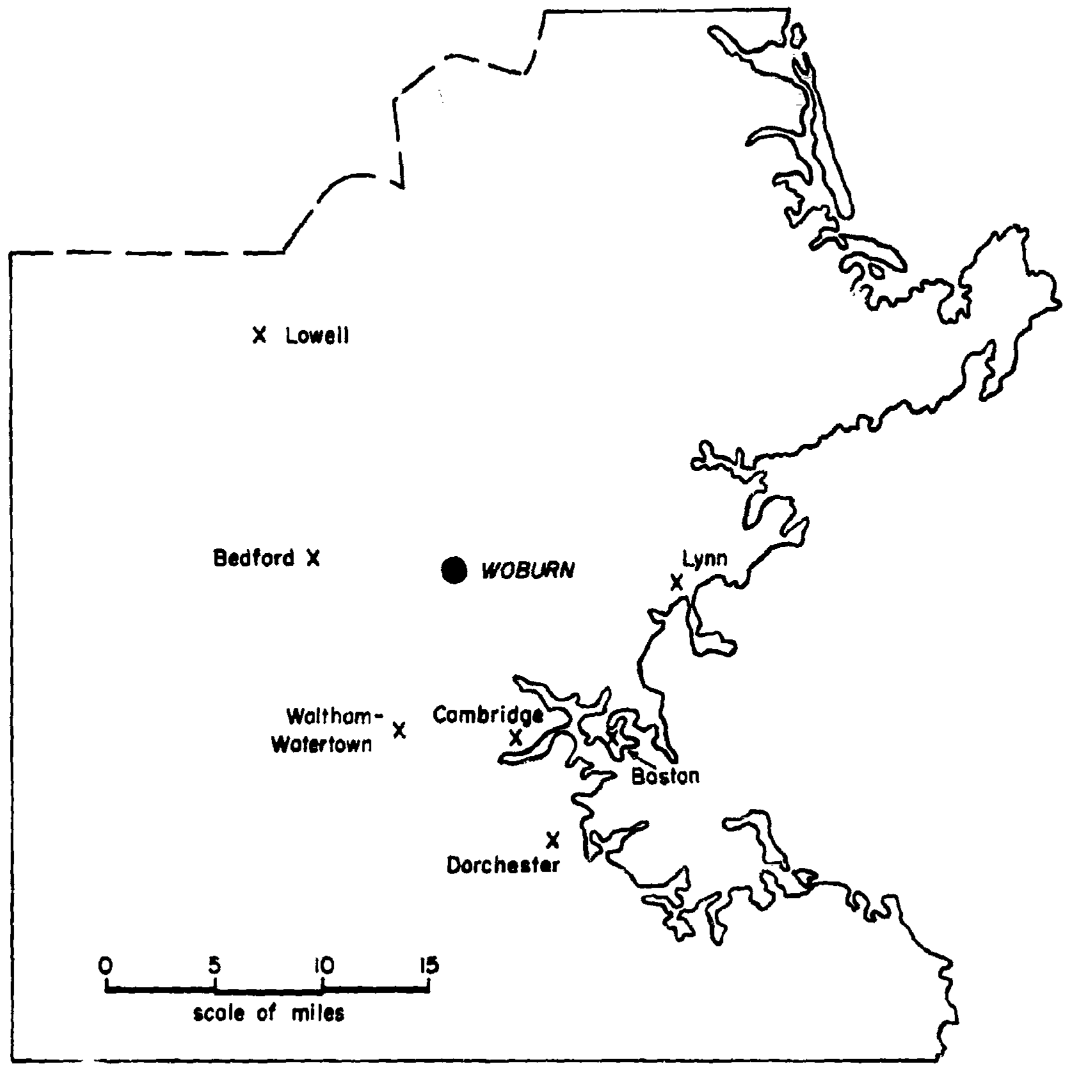

Fig. 6.1 GREATER BOSTON AREA SHOWING ASSUMED SEVEN GROUND ZERO LOCATIONS IN RELATION TO MODEL CITY OF WOBURN

6.22 The Wind and Fallout Situation

The wind pattern assumed for the fallout analysis was that of an actual spring day — May 11, 1959 — when the RAWIN data was typical for the area during the spring and summer season. The 80,000-foot integrated wind direction was 110°, the wind speed 27 mph, and the wind shear 11°. A two-day dose fallout pattern using the shorthand method described in Chapter 4 of Report No. TO-B 60-13 was developed for this wind condition and is shown in Figure 6.2

By placing the fallout pattern on upwind targets further away from the model city than the seven noted above, it was determined that there would be no appreciable fallout from any other targets. The two-day dose on Woburn due to each of the seven nearby targets is listed in Table 6.2. Only two of the seven targets (Bedford and Lowell) are in the general upwind direction from Woburn, and about two-thirds of the total fallout on the city was due to the 5-MT weapon dropped on Hanscom Air Force Base in Bedford. The gross radiation levels over the city ranged from only 1500 r to 1700 r. This very small gradient across the city can be attributed to the several different directions from which fallout arrived.

If the wind had been such as to maximize the fallout from the Bedford weapon, the two-day dose due to this one weapon would have been 1200 to 1800 r, and the over-all total due to the seven weapons, about 2000 r. The fallout over Woburn was also determined for the mean seasonal winter wind and found to be about 2000 r, which tends to suggest that this figure is rather insensitive to the expected variations in wind conditions during the four seasons.

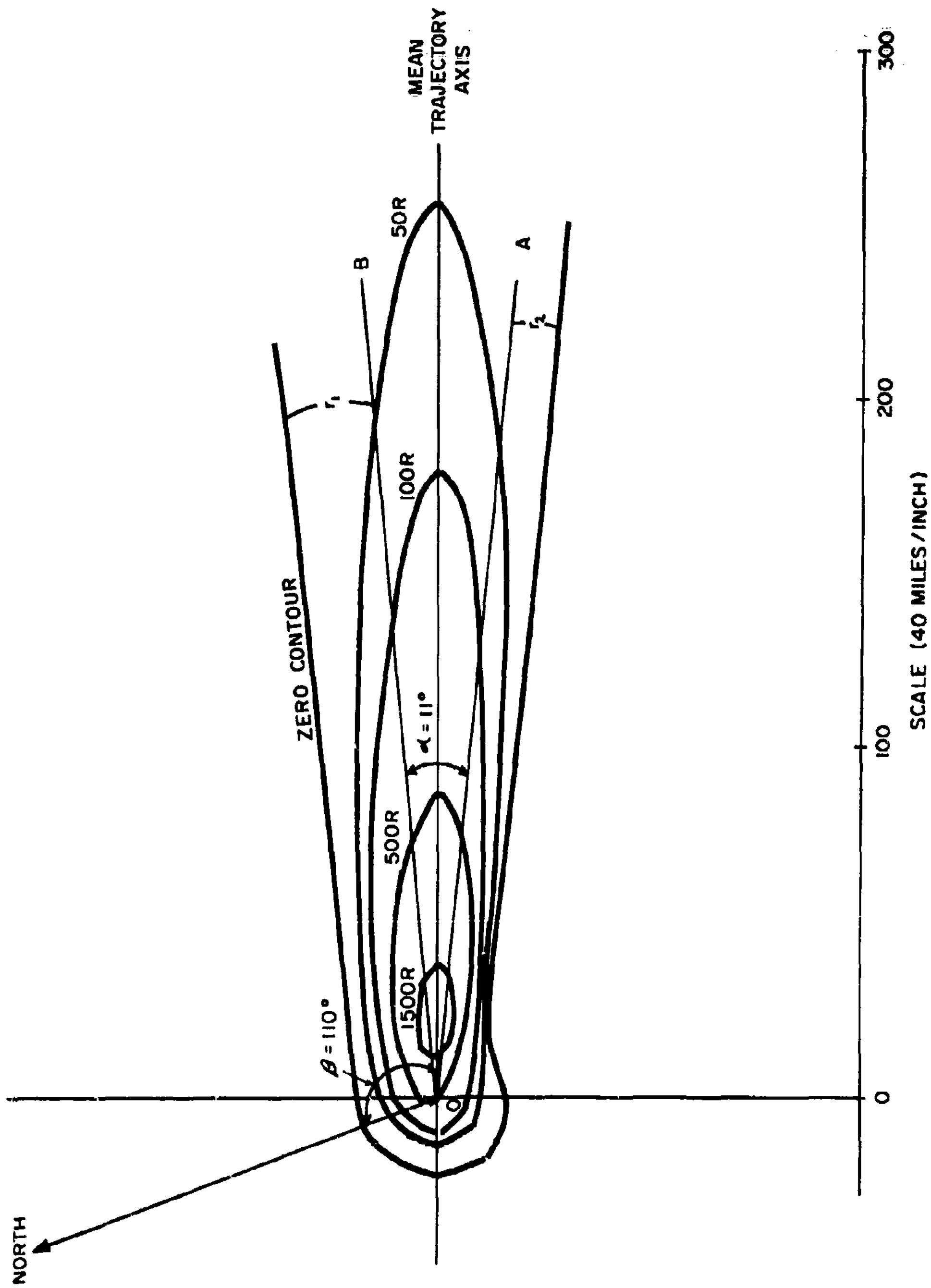

Fig. 6.2 ESTIMATE OF 2-DAY DOSE CONTOURS FOR 5 MEGATON WEAPON USING UF WIND DATA RECORDED AT NANTUCKET, MASS. ON MAY 11, 1959

6.3 THE SHELTER PROBLEM

6.31 Shelter Factors and Spaces in Public and Private Buildings

With the cooperation of city officials, a list of all public buildings and churches in Woburn which were thought to offer substantial fallout shelter was drawn up and reviewed. After taking a closer look at each of these structures, those that obviously offered even less shelter protection than the average home basement were removed from the list. An example of the kinds of structures removed were the newer schools that are of one-story construction, have no below-ground-level areas, and large window areas. In addition, to the public and private buildings of non-profit organizations, each of the twelve industries in the city that employ over 50 people, and seven out of 23 industries employing between 25 and 50 people were contacted to determine the shelter potential of their buildings. Of the larger industries, only 3 out of 12 had substantial multi-story buildings with areas below grade, and none of the smaller ones had either multi-story construction or areas below grade. Of the commercial establishments in the city, only two were found to have reasonably-sized basements, and each of these were only one-story buildings with an estimated shelter factor of 15 to 20.

The final list used for the communal shelter survey consisted of eleven school buildings, 14 churches, and five other public buildings for a total of 30 structures. Unfortunately, building plans for almost none of the structures surveyed could be located, hence physical measurements together with "engineering guesses" had to be made in almost every case to get sufficient information to allow calculation of the shelter factors. The OCDM "Guide for Fallout Shelter Surveys" (April 1959 Edition) was used in carrying out the data collection and shelter factor calculations, the results of which are summarized in Table 6.3.

The immediate conclusion one is forced to draw from this table is that just two buildings (the City Hall and St.*Charles High School with shelter space for 268 people) offer a shelter protection factor of 100 or more. In fact the shelter factor for all the remaining 28 buildings surveyed fell within the narrow range of just 10 to 30, implying that they are no better than the average home basements in the city. (The city engineer stated that more than 90% of the homes in the city have basements.)

TABLE 6.3

SHELTER FACTORS AND SPACES PROVIDED IN THE BASEMENTS OF SCHOOL BUILDINGS, CHURCHES AND OTHER PUBLIC BUILDINGS IN WOBURN, MASSACHUSETTS

Name of Building	Ground Contri-bution	Roof Contri-bution	Shelter Factor	Roof Contribution with 90% of Roof Contaminant Removed	Shelter Factor with 90% of Roof Contaminant Removed	Gross Area	Shelter* Spaces
Schools							
St. Charles High	.001	.005	179	.001	500	2,340	54
Woburn Sr. High	.003	.028	32	.003	167	11,500	268
St. Charles	.013	.025	26	.003	63	5,300	124
Hanson	.008	.033	25	.003	91	3,000	70
Wyman	.007	.044	20	.004	91	6,000	140
Goodyear	.008	.045	19	.005	77	6,700	151
Lawrence	.020	.033	19	.003	44	2,780	65
Clympton	.019	.039	17	.004	44	4,500	105
Rumford	.020	.043	16	.004	42	5,500	128
William McGarr	.028	.037	15	.004	31	3,920	91
Andrew	.011	.055	15	.006	59	12,000	280
Churches							
First Baptist	.012	.038	20	.004	63	6,000	140
Greek Orthodox	.007	.049	18	.005	84	5,400	126
Church of the Open Bible	.020	.039	17	.004	42	9,500	221
Woburn Unitarian	.018	.043	17	.004	46	5,500	128
Woburn Methodist	.018	.040	16	.004	46	5,700	133
First Congregational	.019	.050	15	.005	42	10,500	245
St. Barbara's	.017	.061	13	.006	44	11,000	256
St. Joseph's	.025	.060	12	.006	32	4,300	100
St. Charles'	.008	.074	12	.007	69	3,200	75
Montvale Cong.			15		40	500	12
Trinity Episcopal			15		40	2,000	47
Lutheran Church of The Redeemer			15		40	2,400	56
St. John's Baptist			15		40	2,000	47
No. Congregational			15		40	500	12
Other Buildings							
City Hall	.0006	.0006	830	.0006	1600	9,200	214
Choate Hospital	.006	.032	26	.003	110	16,500	384
Public Library	.0004	.047	21	.005	187	11,000	256
Post Office	.003	.052	18	.005	130	6,000	140
State Armory	.011	.083	11	.008	52	17,000	396
					TOTALS →	191,740	4,464

* Using a shelter utilization factor of 0.35, and assuming 15 square feet of net space per person as set forth in the OCDM "Guide for Fallout Shelter Surveys"

In summary, the churches are for the most part large, heavy-walled structures with very little mass between the basement and the roof, while the schools generally have a substantial portion of their basement exposed and are two- or three-story buildings with wood floors. In each case the roof contribution is the limiting factor — running from two to as much as ten times the ground contribution as can be seen in the table. This fact suggested that if most of the roof contaminant could be removed by some means, the shelter factors could be increased by a factor of three or four. The column of Table 6.3 showing the shelter factor with 90% of the roof contaminant removed demonstrates that this is in fact the case with the shelter factors now ranging from about 40 to 100.

Even if these more desirable shelter factors could be assured by the installation of an effective roof decontamination system, the table shows the total number of shelter spaces totalling only 4500 — or less than 20% of the city's 1955 population of about 26,000. The space situation is not believed to be this bad, however, since a space utilization factor of 0.35 was used for the numbers shown in the table, but for the buildings analyzed, the actual space available is probably more nearly 0.70. If, in addition, the number of square feet allowed per person were halved -- to 7-1/2 square feet -- some 70% of the town's population could be housed in these "communal" type shelters. This would, of course, make for a very uncomfortable situation, but assuming some kind of excursion schedule, such as that suggested in Table 6.4, Section 6.4, the situation should not be unbearable.

6.32 Roof Decontamination Systems

Since all but two of the 30 public and private buildings surveyed were found to offer substantially no better shelter factor than the average home basement, and more than 90% of the homes have basements, a communal shelter plan utilizing public buildings can not be recommended unless some practical and economical method can be found to increase the shelter factor of these buildings by at least a factor of three or four. One possible method would be to provide additional shielding material in the basement, but this does not appear attractive from either an economic or engineering standpoint, since it basically would mean putting up a ceiling of at least 50 lbs/ft^2 over the entire shelter area plus all the mechanical support for this added weight.

A second possible method, which was referred to in the previous section, would involve removing most of the contaminant from the roof, thereby getting an additional factor of three or four improvement in the shelter protection provided by the structures (as demonstrated in Table 6.3). Although other systems have been proposed (such as removable covers, etc.), a water washdown system is the only tactical reclamation system that has ever been proof tested on land structures. Experiments have shown 90% of slurry fallout and 97% of dry fallout can be removed from an asphalt or tar and gravel built up roofing by hosing the roof at 60 psi pressure.*

The efficiency of a network of spray nozzles distributing water uniformly to an entire roof surface has been demonstrated in the laboratory to be in excess of 99% for wet contaminants and could be installed at a cost of about $28 per linear foot of building length including pumps, piping and installation supplying between .02 to 0.1 gallons per minute per square foot of surface area.** The small amount of experimental work done to date on actual roofing materials suggests that a properly designed system could be expected to remove at least 95% of the fallout from the roof if the roof is smooth, hard and wettable where composition roll roofing represents the minimum in smoothness and surface hardness. The water flow rate to accomplish this by maintaining coverage would be three gallons per minute per foot of roof width.***

The communal shelters in Woburn have either asphalt shingle or slate roofs with a nominal size of 50' by 100'. This would require about 300 gallons per minute, and assuming operation for a period of about six hours, would result in the consumption of 108,000 gallons of water per shelter. Thirty such shelters would in fact take all but 70,000 gallons of the 1958 average daily consumption of 3,310,000 gallons (i.e. 98% of the average daily consumption). An emergency pumper is available in the town which can pump 2 million gallons a day, or about 60% of the required amount of 3,240,000 gallons. If the washdown systems were actually on only intermittently for a total of 3 hours over a 6-hour period, then the emergency pumper could theoretically supply the required load of about 50,000 gallons for each of the 30 shelters. However, the water pressure would undoubtedly start to drop pretty rapidly under this abnormally high load.

* Radiological Recovery of Fixed Military Installations NAVDOCKS TP-PL-13, August 1953.

** Fallout Countermeasures for AEC Facilities, A. J. Breslin and L. R. Solov.

*** NRDL Letter Report to OCDM, dated November 7, 1958.

One other possible roof contaminant removal system requiring only 500 to 1000 gallons of water for each shelter was investigated briefly during this study. It involved the use of a standard fire fighting foam which could be sprayed onto the roof as a "blanket" to catch and hold fallout for a period of perhaps 30 minutes. The foam blanket would then be flushed off and a new blanket laid down. This process would be repeated for, say, five or six cycles, or until further flushings no longer resulted in a significant reduction in the dose level inside the shelter. The foam to be effective must, of course, stick to the roof and hold the fallout particles until it is flushed off.

A demonstration on the use of several varieties of foam for this proposed application was witnessed, and the results indicated that the foam would not stay in place for more than a few minutes before starting to slide off a roof with a pitch of only 10°. The reason for this is that the water in the protein based foam starts to settle out of the foam within a few minutes after it is formed, and the liquid interface then starts to carry the foam off the inclined plane. There was also some question as to how well the foam could "hold" the fallout particles (i.e., keep them off the surface of the roof). Sand particles of 100 to 300 microns were thrown onto the foam and observed to penetrate at least well into the blanket if not all the way through it. Although it is felt that further research should be conducted in an effort to find a foam material with greater stability and consistency for use in possible roof decontamination schemes, fire fighting foams do not appear at present to offer a solution to the roof decontamination problem.

6.4 SUMMARY OF SHELTER SITUATION AND OTHER ESSENTIAL RESOURCES IN WOBURN

6.4.1 Exposure Doses for the City's Population

Assuming a probable two-day dose of about 2000 r as developed in Section 6.2, those people who remained outside after the arrival of fallout or who relied on their home above ground for shelter would not survive. However, those that were aware that their cellar afforded a shelter factor of 10 to 30 and remained in the cellar or in one of the communal type shelters without a roof contaminant removal system would survive though they would probably not be able to venture out of their shelter for more than the briefest excursions for a period of two weeks without becoming radiation casualties.

On the other hand, for those in communal shelters with a roof contaminant removal system (or in improvised home basement shelters as described in Chapter 5), excursions out of shelter designed to keep the two-week dose less than 100 r, or less than 200 r, might be scheduled as shown in Table 6.4.

TABLE 6.4

EXCURSION SCHEDULE OUT OF COMMUNAL SHELTERS IN WOBURN WITH A ROOF CONTAMINANT REMOVAL SYSTEM
(assuming area received a 2000 r, two-day dose and a shelter factor of 50)

	Time Spent Outside	
End of Day	for 100 r 2 Week Dose (in hours)	for 200 r 2 Week Dose (in hours)
2	1/2	1-1/2
3	3/4	2-1/4
4	1	3
5	1-1/2	4-1/2
6	1-3/4	5-1/4
7	2-1/4	6-3/4
8	2-1/2	7-1/2
9	3	9
10	3-1/4	9-3/4
11	3-3/4	11-1/4
12	4-1/4	12-3/4
13	4-1/2	13-1/2
14	5	15

At the end of the first two days in the communal shelter, each person's or family's schedule could be worked out on an individual basis. Depending on the condition of shelter in one's home and the length of time it would take to get home, there could be a gradual migration to the residences. The leader of the communal shelter should be in a position to evaluate the radiation history of the family, calculate the time for the family to get home, determine a cellar, home and outside schedule for them outlining the consequences of any deviation from this schedule.

6.42 Food, Water and Utilities

If everyone provided themselves with just a half gallon of water to satisfy their drinking need for the first two days, action could be taken to provide water service for the city from the underground wells available. In a similar manner, if each individual brought a two-day food supply with him to the communal shelter, food could be supplied from D + 2 to D + 14 by the retail markets which generally carry a supply of groceries which would last about two weeks under a normal purchase schedule.*

The 1957 Retail Food Inventory Survey, conducted by the bureau of census for the U. S. Dept. of Agriculture in line with the Department's delegation from OCDM indicated that slightly more than ten days supply of food, including non-concentrated fluids, was in retail food store inventories of the nation at the time of the survey. This is based on 3000 calories per person per day; however, it is estimated that under a sedentary condition one would exist on less than this amount. This would indicate that the nation would be supplied with food from their home and retail outlets to D + 14 from home and retail supplies. After two weeks, food should be able to start moving from wholesale houses and farms again.

Woburn can be supplied with power from any of three local generating stations. Power may also be supplied to the system from a western link. The Edgar Generating Station is over seven miles from the closest ground zero location and hence should suffer only minor blast damage. Gas is supplied to Woburn by a company which manufactures gas in two nearby towns, one of which should be relatively blast-free. Their system is also supplied by the Tennessee Gas Transmission Company and the Algonquin Gas Transmission Company; hence, gas supply to Woburn seems to be flexible in the event of a nuclear attack since the separate supplies have interconnections at several locations.

* Super Value Study Editors of Progressive Grocer

6.43 Conclusions

1) A communal shelter program for typical suburban cities of 15,000 to 40,000 population where the percentage of structures with basements is high is feasible without additional construction only if an effective roof contaminant removal system is available. Roof washdown systems are effective, but use larger quantities of water than may frequently be available from commercial supply systems. Other possible contaminant removal systems using much less or no water have not proved practical as yet. However, further research should be carried on in an effort to develop a practical, economic roof decontamination system for communal shelter use.

2) If good shelter (i.e., substantially better than the average home basement) were available to the residents of the model city, recovery operations could be initiated after two days, and significant progress made by the end of the second week provided the area was not hampered by major blast damage.

3) Availability of food and utilities does not appear to present a serious problem to survival in the model city chosen.

CHAPTER 7

THE NET SHELTER PROBLEM

The following generalizations can be made concerning the amounts and effectiveness of shelter from radioactive fallout that is readily available, assuming enough time (in the order of hours) for some large-scale population movement:

1) Basement shelter is available to approximately 60% of the population of the continental United States, and is probably the best over-all source of shelter when available.

2) Shelter in boats (at least 250 yards off shore) is of some significance in 32 states, and might take care of as much as 9% of the population of the United States. There are hundreds of communities without adequate home basements or public buildings which might find it relatively easy to organize their boat shelter. Many of these vessels already have most of the facilities necessary to make them adequate as shelters; however, these facilities will in general have to be increased greatly in order to provide the maximum shelter capacity.

3) The use of mines for shelter from fallout is of some significance in 27 states and might take care of as much as 8% of the population. Mine shelter, where available and appropriate, would provide excellent protection against fallout. The cost to outfit mines as shelters should be relatively low and they may also prove to be quite easy to manage. The limiting factors on this type of shelter are that, in general, the mines are far more remote than either basements or boats. They are the most difficult for people to get into and require the greatest amount of pre-planning.

4) The access problem is sufficiently great for both boats and mines that it is unlikely that more than 7% of the population would choose to be accommodated in either of these facilities.

Table 7.1 outlines the Net Shelter Problem. The percentage of each state's population that could be accommodated in basement, boat or mine shelter and the numbers of people who could not be accommodated are shown

TABLE 7.1

SHELTER FROM RADIOACTIVE FALLOUT IN BASEMENTS, BOATS AND MINES
Per cent that could be accommodated and number of people who could not be accommodated

Region	State	1960 Population (in 1000's)	Per cent with Access to Basements	Boats*	Mines*	Total Per cent Accommodated	People not Accommodated (in 1000's)
OCDM 1	Conn.	2,007	90	2	—	92	160
	Maine	914	99	1	—	100	—
	Mass.	4,691	95	5	—	100	—
	N. H.	533	99	1	—	100	—
	N. J.	4,835	85	1	—	86	690
	N. Y.	14,830	90	10	10	100	—
	R. I.	792	90	7	—	97	20
	Vt.	378	99	1	1	100	—
		28,980					870
OCDM 2	Del.	318	60	40	—	100	—
	D. C.	802	70	2	—	72	220
	Ky.	2,945	60	4	15	79	630
	Md.	2,343	70	30	—	100	—
	Ohio	7,947	90	9	10	100	—
	Pa.	10,498	99	1	1	100	—
	Va.	3,319	70	18	1	89	360
	W. Va.	2,006	60	—	40	100	—
		30,178					1,200
OCDM 3	Ala.	3,062	10	15	1	26	2,260
	Fla.	2,771	<1	24	—	24	2,110
	Ga.	3,445	20	9	1	30	2,410
	Miss.	2,179	10	1	—	11	1,940
	N. C.	4,062	40	3	—	43	2,310
	S. C.	2,117	30	3	—	33	1,420
	Tenn.	3,292	40	2	8	50	1,650
		20,928					14,100
OCDM 4	Ill.	8,712	80	2	14	96	350
	Ind.	3,934	80	—	5	85	590
	Mich.	6,372	85	4	15	100	—
	Mo.	3,955	70	10	30	100	—
	Wisc.	3,435	85	3	15	100	—
		26,408					940
OCDM 5	Ark.	1,910	20	—	1	21	1,510
	La.	2,684	5	43	23	71	780
	N. M.	681	10	—	90	100	—
	Okla.	2,233	20	—	80	100	—
	Tex.	7,711	10	18	1	29	5,480
		15,219					7,770
OCDM 6	Colo.	1,326	40	—	—	40	800
	Iowa	2,621	70	—	4	74	680
	Kan.	1,905	50	—	50	100	—
	Minn.	2,982	85	4	1	90	300
	Nebr.	1,326	70	—	5	75	330
	N. D.	620	85	—	—	85	90
	S. D.	653	80	—	—	80	130
	Wyo.	291	70	—	—	70	90
		11,723					2,420
OCDM 7	Ariz.	750	10	-	2	12	660
	Calif.	10,586	15	26	3	44	5,930
	Nev.	160	20	—	31	51	80
	Utah	689	30	—	—	30	480
		12,185					7,150
OCDM 8	Idaho	589	60	—	—	60	240
	Mont.	591	70	—	—	70	180
	Ore.	1,521	50	50	—	100	—
	Wash.	2,379	50	24	—	74	620
		5,080					1,040
TOTALS:		150,701	60	9	8	77	35,490

* Boat and mine percentages are not necessarily maximum values, unless the total of basement, boat and mine shelter is less than 100% of the state's population.

There are more than 35,000,000 people (based on the 1950 Census), principally in the south and southwest, for whom no basement, boat or mine shelter is readily available. As shown in detail in Figure 7.1 and Table 7.1, the two states with the most serious shelter problems are California and Texas. There does not appear to be natural shelter for nearly 6,000,000 Californians who constitute more than 40% of the state's population, and more than 5,000,000 Texans or some 30% of that state's population. The southeastern states (OCDM Region 3) have more than 14,000,000 people who do not have access to natural shelter for fallout and they constitute more than 70% of the population of that region.

A comparison of these figures with the target list in Report TO-B 60-13 shows that within these large shelter-deficient areas, the three "worst" areas are:

1) Fort Worth and Dallas, Texas — These cities are very important military and industrial targets with large populations, very little basement shelter, no boat and no mine shelter.

2) Atlanta, Georgia — This city is an important industrial and military center with a large population, very few basements, few boats and no mine shelter.

3) Los Angeles, California — This city is a very important industrial and military center with a very large population, very few basements, many boats but limited access to them by the population, and no mine shelter.

In terms of the percentage of the population in any state who do not have access to any kind of natural shelter, there are two states, Arizona and Mississippi, for whom fewer than 20% of the people have such access. There are seven states, Alabama, Florida, Georgia, South Carolina, Arkansas, Texas and Utah, in which fewer than 40% of the population have access even to fairly remote natural shelter.

It is perhaps significant that in terms of numbers of people and particularly per cent of the population, the areas most seriously lacking in adequate shelter from radioactive fallout are far distant from the heavily-industrialized and densely-populated northeastern and northcentral states. The presence, however, of large numbers of military targets and considerable industrial capacity in the southern and southwestern states makes it quite likely that high intensities of radioactive

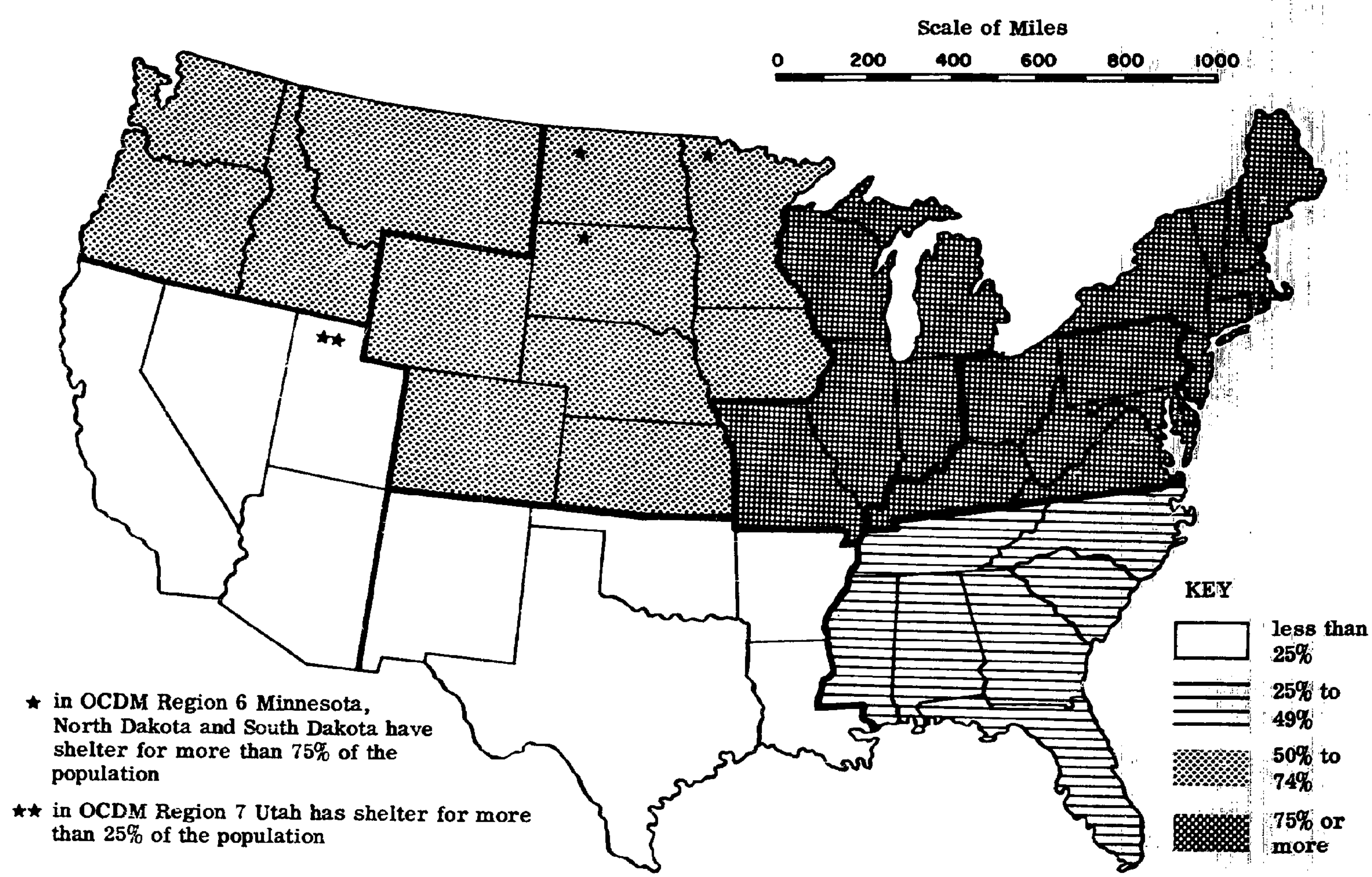

Fig. 7.1 AVAILABLE SHELTER FROM RADIOACTIVE FALLOUT IN BASEMENTS, BOATS AND MINES (by OCDM regions) Approximately 2/3 of the Population of the Continental United States Has Access to Shelter

fallout would spread over the densely-populated areas in the event of nuclear attack. Shelter from fallout in these areas may be a far more serious problem both in time and in money than it appears to be in the critical industrial heartland of the north. In terms of people per state who do not have even remote access to good fallout shelter, the ten most needy states may be ranked in order of decreasing numbers as follows:

State	Number of People Without Access to Shelter
California	5,900,000
Texas	5,500,000
Georgia	2,400,000
North Carolina	2,300,000
Alabama	2,300,000
Florida	2,100,000
Mississippi	1,900,000
Tennessee	1,700,000
Arkansas	1,500,000
South Carolina	1,400,000

As noted previously all tables use 1950 Census data. A recalculation based on the recent 1960 Census would undoubtedly show that all the above figures are somewhat low. The totals for California and Texas may now be as high as 8,000,000. The total for Florida has probably risen faster than for the other southeastern states so that it would be in third place in the list of states most in need of shelter. Other than the reordering for Florida the rank-order for the ten neediest states is not likely to change.